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Los Angeles

Collectivism and the Psychophysiology of Self-Regulation in Adolescents

A dissertation submitted in partial satisfaction of the requirements for the degree

Doctor of Philosophy in Psychology

by

Amy Meryl Rapp

2019

ABSTRACT OF THE DISSERTATION

Collectivism and the Psychophysiology of Self-Regulation in Adolescents

by

Amy Meryl Rapp

Doctor of Philosophy in Psychology

University of California, Los Angeles, 2019

Professor Denise A. Chavira, Co-Chair

Professor Gregory A. Miller, Co-Chair

Collectivism, a cultural value which emphasizes interpersonal relationships and group cohesion, is endorsed to a greater degree among Latinx and Asian individuals than non-Latinx White (NLW) individuals and is thought to increase the salience of social context. The relationship between collectivism and social context may account for higher levels of social anxiety reported by Latinx and Asian adolescents. In line with this premise, errors or negative feedback that take place in a social context may be viewed by those with a collectivistic worldview to have greater consequences than to those with an individualistic perspective. Exaggerated error monitoring and response to negative feedback already have been implicated in models of social anxiety. The goal of this study is to determine the extent to which adolescents' endorsement of collectivism interact with neural manifestations of error-monitoring (i.e., error-related negativity (ERN)) and feedback response (i.e., feedback-related negativity (FRN)) occurring in a social context, and the magnitude of the association of these event-related brain components with dimensional ratings of social anxiety. A community sample of Latinx, NLW, and Asian adolescents (*n*=102) was recruited for this study. Participants completed three complementary computerized speeded-response and feedback response tasks designed to elicit the ERN and FRN, as well as a battery of self-report questionnaires assessing demographic, cultural, and psychopathology constructs. Results from regression models supported the hypothesis that collectivism increases the salience of social context for adolescents, which is reflected in enhanced neural response to errors. Further, both ERN and FRN were found to be related to a dimensional measure of social anxiety. These relationships appear to be contingent on certain factors, namely, how social context is represented and the valence of social feedback. This project also found racial/ethnic group to be a moderator of identified associations. Although findings from this study are limited by methodological and conceptual issues, results could be used to inform future translation efforts of psychophysiological insights into treatment innovations.

The dissertation of Amy Meryl Rapp is approved.

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2019

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Acknowledgements

This work was supported by a Ruth L. Kirschstein National Research Service Award Individual Predoctoral Fellowship (F31MH111187) funded by the National Institute of Mental Health. Research costs were partially supported by awards from the American Psychological Association of Graduate Students, the Society of Clinical Child and Adolescent Psychology, and the Society for a Science of Clinical Psychology.

Abbreviated Curriculum Vitae

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Publications

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Introduction

Latinx individuals in the United States (U.S.) face a number of mental health disparities in terms of rates, severity, and impairment due to psychological disorders, as well as in receipt of services. As the largest ethnic minority group in the U.S. (U.S. Census Bureau Population Department, 2015a), with a rapidly growing population projected to comprise 28.6% of the nation's population by 2060 (U.S. Census Bureau Population Department, 2015b), such disparities are critical to address. Much research has focused on dissemination and implementation of evidence-based treatments as a means of improving psychological outcomes of this underserved group. Certainly, increased access to care is an important step for reducing disparities for Latinx individuals. However, it is at least as important that the treatments intended to be disseminated to community settings are targeted and effective for this group. As such, a critical goal for the field is to develop personalized interventions that are built on a culturally-informed understanding of the factors that influence risk and resilience for mental illness among Latinx individuals.

More specifically, there is a great need to understand the etiology of anxiety disorders among Latinx individuals. Across studies, Latinx children and adolescents are shown to be at greater risk for developing anxiety, are more likely to fall in the clinical range of internalizing symptoms on standardized assessment measures, and report higher levels of worry than do non-Latinx White (NLW) counterparts (Achenbach & Rescorla, 2000; Achenbach & Edelbrock, 1987; Gross et al., 2006; La Greca, Silverman, Vernberg, & Prinstein, 1996; McLaughlin, Hilt, & Nolen-Hoeksema, 2007; U.S. Department of Health and Human Services, 2001; Shannon, Lonigan, Finch, & Taylor, 1994; Varela, Vernberg, Sanchez-Sosa, Riveros, Mitchell, & Mashunkashey, 2004; Wasserstein & LaGreca, 1998). Social anxiety in particular is relevant within Latinx populations, with evidence for an undue disease burden. In diagnostic interviews, Latinx adults report the highest level of impairment due to social anxiety (Polo, Alegría, Chen, & Blanco, 2011), and on self-report measures, Latinx youth endorse more severe social anxiety than any other racial/ethnic group of youth (McLaughlin, Hilt, & Nolen-Hoeksema, 2007; Polo & Lopez, 2009). Asian youth similarly endorse social anxiety to a greater degree than NLW youth (Austin & Chorpita, 2004; Lau, Fung, Wang, & Kang, 2009) and in Asian and Asian American adult samples, high rates and severity of social anxiety, as well as heightened fears of negative evaluation, have been reported (Kim, & Markman, 2006; Norasakkunkit, & Kalick, 2002; Okazaki, 2000; Okazaki, Liu, Longworth, & Minn, 2002). The reasons for these differences in severity and prevalence rates are not clear; this is an understudied topic and few known correlates of increased risk for social anxiety among these cultural groups have been identified.

Just as social anxiety has been found to be more prevalent among individuals from certain *cultural* groups, there is also a preponderance of social anxiety in certain *developmental* groups, namely adolescents. Nearly 9% of 13-18 year-olds in the U.S. meet lifetime criteria for social anxiety disorder (SAD) (Burstein et al., 2011). The disorder appears to onset disproportionately during adolescence (Beesdo et al., 2010; Stein et al., 2001) with the majority of cases emerging before the age of 23 (i.e., approximately 90% (Stein, 2006)). This age-of-onset distribution is unique relative to other anxiety disorders; while there is steady increase in onset during the early twenties for generalized anxiety disorder and panic disorder, a plateau is observed for SAD (Beesdo et al., 2010).

A common factor between the aforementioned cultural and developmental groups is that social context is perceived to be highly salient. For Latinx and Asian individuals, this may in part be attributable to the cultural value of collectivism (Oyserman, Coon, & Kemmelmeier, 2002), an attitudinal orientation that emphasizes connectedness with others, places a high value on harmonious interpersonal relationships, and engenders a belief that individuals should be attentive to the unexpressed thoughts and feelings of others and adjust their behavior in response (Singelis, 1994). Also characterized by greater prioritization of interpersonal relationships, adolescence is often conceptualized as a "sensitive period for social processing" (Blakemore & Mills, 2014) during which adolescents are more oriented toward peers (Barnes, Hoffman, Welte, Farrell, & Dintcheff, 2007; Larson, 2001) and perceive interactions with peers as highly rewarding (Rubin, Bukowski, & Parker, 2006).

As such, this project draws from complementary but mostly separate literatures to explore neural vulnerability to psychopathology during adolescence with a particular focus on Latinx adolescents, an understudied and underserved group. The overarching goal of the present project is to identify pathways by which an individual's view of themselves and their connection to others play a critical role in determining the implicit meaning of immediate social context, neural responses to social stimuli, and the role of those factors in normal and pathological anxiety. In line with a developmental neuroscience approach, findings from the present study may be leveraged to uniquely understand how social experiences impact neural systems during periods of relative plasticity, in an effort to identify opportunities for early intervention and prevention (Suleiman & Dahl, 2017).

Culture, Development, and Neurobiological Processes Jointly Contribute to the Emergence of Social Anxiety in Adolescence

Some argue that the brain is not innately social (Atzil, Gao, Fradkin, & Feldman Barrett, 2018), with neural circuits involved in social processing coming online as a result of early experiences (Andersen, 2003; Feldman, 2007). Brain development occurs over a protracted period of time (i.e., spanning from in utero up to 25 years postnatal (Stiles & Jernigan, 2010)), allowing environmental inputs to have considerable impact on behavior and functioning (Curley & Champagne, 2016; Johnson, 2001). This understanding highlights the obvious importance of considering the role of culture during key developmental periods, especially when attempting to elucidate how psychopathology emerges. Increasingly, there has been recognition of cultural experiences in developmental psychopathology (Causadias, 2013; Causadias and Cicchetti, 2018). Conceptual models derived from this work recognize cultural risk, protective, and promotive factors as operating on multiple levels to influence trajectories of normal and abnormal behavior (Causadias, 2013). Cultural development, in which individuals are immersed in societal- and individual-level processes that shape one's self-concept, is a normative process all people undergo. This process of identity formation critically coalesces during adolescence (Fuligni & Tsai, 2015). Unsuccessful navigation of this period of fundamental change may result in dysfunction that sets a youth up for a difficult transition to adulthood (Côté, 2009), particularly if competence in social domains is not achieved. Indeed, inability to obtain acceptance from peers and/or affiliate with a peer group has been shown to have broad, enduring, and cascading effects on functional outcomes (Masten & Cicchetti, 2010; Parker, Rubin, Erath, Wojslawowicz, & Buskirk, 2006).

During adolescence, cultural and developmental shifts interacting with maturing neural pathways set the stage for increased vulnerability for psychopathology (Serafica and Vargas, 2006). Risk for social anxiety specifically has been linked with increased salience of and sensitivity to social context. Some have described this heightening of sensitivity to social context as a process of affective "tuning" during which biases emerge in response to adverse or supportive aspects of the social environment (Pluess, 2015). Tuning occurs through learning and characterizes how an individual responds to social contexts throughout development. Environmental characteristics such as caregiver practices have been shown to interact with brain structure and function to influence outcomes in youth by sensitizing social-affective circuitry and influencing how inputs are assigned value in a manner that can both promote risk and confer protective effects. For example, research has shown that early-life family adversity is associated with neural hyperactivity when processing threatening stimuli (Maheu et al., 2010) and maternal warmth in early childhood is associated with diminished neural response to negative events in brain regions that process social and emotional information (Morgan et al., 2014). These family-level experiences in childhood are thought to lay the foundation for how neural sensitivities will manifest in adolescence, and subsequently, the degree to which peer interactions, which become increasingly salient during this developmental period (Steinberg & Morris, 2001), impact outcomes. Illustrative of this concept is research by Tan and colleagues (2014) demonstrating that negative maternal affect during a challenging task that required supportiveness from mothers was associated with attenuated adolescent responsiveness to peer acceptance in brain regions involved in social-affective processing. Together, this evidence suggests a model of neurobiological susceptibility to social contexts that is largely a product of early-life and ongoing environmental experiences (Agrawal, 2001) and supports the adoption of an interdisciplinary, multiple units of analysis approach when examining the interplay of culture, development, and psychopathology (Cicchetti & Toth, 2015).

How Can We Enhance Etiological Models to Address Racial/Ethnic Disparities?

Application of the National Institute of Mental Health (NIMH) Research Domain Criteria (RDoC) framework has been discussed as one strategy for understanding differential pathways to mental illness that contribute to disparities in prevalence and impairment (Gordon, 2018). This approach is particularly well suited for an investigation of how cultural and developmental factors interact with neurobiology to influence social anxiety outcomes. RDoC incorporates multi-domain (e.g., neurobiological and psychological) units of measurement that can be linked to specific impairments associated with clinical abnormality (National Institute of Mental Health, 2008).The RDoC initiative advocates increased granularity in investigations of clinical conditions. That is, it cannot be assumed that higher-order psychological constructs (e.g., categorically defined psychiatric disorders) map neatly onto a simpler biological mechanism (Kozak & Cuthbert, 2016) or that mappings are equivalent across the population. Instead, the RDoC approach foregrounds specific, clinically-relevant dimensions by identifying intermediate psychological and biological mechanisms known as endophenotypes that are associated with impairment (Miller & Rockstroh, 2013; Miller, Rockstroh, Hamilton, & Yee, 2016). Because of the complexity of isolating genetic contributions to psychological disorders, identifying the characteristics the mediate the path from genes to behavioral expression (i.e., endophenotypes (Gottesman & Gould, 2003)) is a potentially less unwieldy avenue of study. As such, neural processes related to error monitoring and feedback response, which have been implicated in etiological models of social anxiety, have begun to be investigated as candidate endophenotypes (Riesel et al., 2019; Harrewijn, van der Molen, van Vliet, Tissier, & Westenberg, 2018). Such investigations, designed to be in line with the RDoC framework, could be leveraged to address mental health disparities by translating insights regarding culturally-influenced individual differences in dimensional biological and psychological constructs into treatment innovations.

Error monitoring and the error-related negativity. Error monitoring is considered a critical aspect of self-regulation—it allows individuals to detect errors and alter behavior accordingly (Gehring, Goss, Coles, Meyer, & Donchin, 1993; Gehring, Liu, Orr, & Carp, 2012). In the context of normative anxiety, error monitoring may serve an adaptive role by motivating individuals to attend to a possible threat to one's well-being and/or pursuit of a goal and respond effectively (Barlow, 2002; Marks & Nesse, 1994). Conversely, exaggerated neural response to error is considered one mechanism by which pathological anxiety may develop.

The error-related negativity (ERN) is a sharp negative voltage deflection in the event-related brain potential (ERP) that peaks within 100 milliseconds (ms) of an error response (Falkenstein, Hohnsbein, Hoormann, & Blanke, 1991; Gehring et al., 1993). Some have conceptualized the ERN as a reflection of individual variance in threat sensitivity that may in turn modulate fear regulation in the form of a person's behavioral response to a potential threat (Proudfit, Inzlicht, & Mennin, 2013). This pattern of neural activity could manifest behaviorally as excessive concern about mistakes or social violations, a hallmark characteristic of social anxiety.

Several theories exist regarding the functional significance of the ERN. Early theories suggest that the ERN reflects error detection, specifically a process in which an individual's response on a task is compared to the best approximation of the correct response (Falkenstein et al., 1991; Gehring et al., 1993). Within this framework, the ERN could be interpreted as a reflection of an effort to use information about the presence of an error to make strategic adjustments that may prevent or correct the error (Gehring et al., 1993; Holroyd & Coles, 2002). Overall, the ERN can be considered to be an early evaluator signal that triggers a cascade of downstream processes (e.g., increased dorsolateral prefrontal cortex and amygdala activation; Kerns, Cohen, MacDonald, Cho, Stenger, & Carter, 2004; van Veen, 2006; Pourtois, Vocat, N'Diaye, Spinelli, Seeck, & Vuilleumier, 2010) that then regulate subsequent emotional reactivity (Danielmeier, Eichele, Forstmann, Tittgemeyer, & Ullsperger, 2011; King, Korb, von Cramon, & Ullsperger, 2010; Ullsperger, King, & Von Cramon, 2008).

Expanding on the error detection/comparator theory, as described above, is research that suggests that the ERN represents an affective response to errors (Luu & Pederson, 2004; Yeung, 2004) and functionally reflects both cognitive and motivational factors (Shankman & Gorka, 2015). A number of investigations have supported this affective/motivational theory and posit that the ERN is responsive to factors that influence motivation to prevent errors (Weinberg, Dieterich, & Riesel, 2015), particularly given that the ERN is thought to represent the degree to which threat is internally generated (i.e., modulations are a result of what the individual perceives to be aversive/salient (Weinberg et al., 2016)). For example, experimental manipulations that enhance the value of errors (e.g., when errors are punished or incur monetary cost; when performance is evaluated) have been associated with increases in ERN magnitude (Chiu & Deldin, 2007; Ganushchak & Schiller, 2008; Hajcak, Moser, Yeung, & Simons, 2005; Riesel, Weinberg, Endrass, Kathmann, & Hajcak, 2012). Similarly, when manipulations are made to attenuate an individual’s concern about errors (e.g., removal of a punishment), the ERN decreases (Riesel et al., 2012). Collectively, these studies suggest that contextual factors, notably a person’s social environment, influence the salience of errors and in turn modulate the ERN (Proudfit, Inzlicht, & Mennin, 2013).

Feedback response and the feedback-related negativity. An ERP component related to the ERN is the feedback-related negativity (FRN), a negative-going component that occurs 250-300 ms following the receipt of feedback (Foti, Weinberg, Dien, & Hajcak, 2011; Gehring & Willoughby, 2002). The FRN has been implicated in reinforcement learning theories and is believed to be part of a process that modifies or reinforces behavior depending on the valence of the outcome (i.e., negative or positive) (Holroyd & Coles, 2002; for review, Nieuwenhuis, Holroyd, Mol, & Coles, 2004). This theory conceptualizes the FRN as representing a "good/bad" evaluation (Hajcak, Moser, Hoylroyd, & Simons, 2006; Yeung, 2004) that contributes to flexible and effective decision making. Impaired ability to appropriately interpret and learn from feedback has been linked with clinical dimensions of social anxiety (Abraham & Hermann, 2015; Stevens, Peters, Abraham, & Hermann, 2014). As such, abnormalities in reward processing as reflected in the FRN have been shown to play a role in the emergence and maintenance of the disorder.

An extension of the reinforcement learning theory is research that demonstrates affective/motivational influences on the amplitude of the FRN. As also seen with the ERN, the FRN is sensitive to both individual-level and contextual factors. For example, FRN amplitude has been shown to vary as a function of motivational states (Gehring & Willoughby, 2002; Holyroyd & Coles, 2002; Gu et al., 2015), the valance and perceived relevance of feedback (Santesso, Dzyundzyak, & Segalowitz, 2011; Severo, Walentwoska, Moor, & Pourtois, 2017), and contextual factors like observation (Voegler, Peterburs, Bellebaum, & Straube, 2019). Together this research suggests that the FRN is not simply a binary evaluative signal but can also reflect subjective perceptions of reward and the context of reward.

Collectivism is Associated with Enhanced Neural Correlates of Self-Regulation

Collectivism is considered an important determinant of cognition and behavior (for review, Han & Ma, 2014). Sociocultural variation in endorsement of collectivism is believed to be manifested at the neural level (Kitayama & Uskul, 2011) and has been shown to modulate neural substrates of perception, attention, and memory (Goh & Park, 2009; Han & Northoff, 2008; Han et al., 2013). Although less is known about the association of collectivism with neural systems related to threat perception, there is a small body of literature that has examined how collectivism influences neural correlates of self-regulatory processes using EEG. This work primarily involved Asian and Asian American samples and utilized varying types of manipulations to elicit social context.

In a study by Park and Kitayama (2014), the image of a face was used to signal a socially-salient source of potential threat. Collectivism was found to be correlated with enhanced neural response to error when primed by a face relative to a control stimuli. This “face priming effect” was more robust among Asian American undergraduates than among European American undergraduates. The authors surmised that for Asian American undergraduates, exposure to facial cues was sufficient to evoke social-evaluative threat to self, resulting in greater vigilance to errors which manifested as enhanced ERN. The face priming effect was also examined in regards to neural response to feedback. It was shown that collectivism was associated with a larger difference score between FRN primed by facial stimuli and FRN primed by non-social stimuli. Collectivism was also found to mediate the association of racial/ethnic group (i.e., Asian American versus European American) and the face priming effect on FRN (Hitokoto, Glazer, & Kitayama, 2016). These studies lend support to the notion that cultural views related to prioritization of interpersonal relationships heighten the impact social cues may have on neural correlates of error-monitoring and feedback response.

Upregulation in error processing as a function of collectivism was also detected when errors were committed in a social condition represented by affiliation (i.e., when earning points to win a prize for a friend) versus a non-social condition (i.e., when earning points to win a prize for oneself) (Kitayama & Park, 2014). In this study, European Americans showed a more negative ERN in the self condition relative to the friend condition whereas there was no difference in ERN between conditions for Asian and Asian American undergraduates. Further, collectivism was found to mediate the association of racial/ethnic group and differentiation between ERN in the self condition and ERN in the friend condition. Findings were more mixed when examining the association of this social context manipulation with variation in neural response to feedback. Two studies were conducted among Chinese undergraduate students and utilized a gambling paradigm in which participants placed bets to win points for different beneficiaries (e.g., self, friend, stranger) (Zhu, Wang, Yang, Gu, Wu, & Luo, 2016a; Zhu, Wu, Yang, & Gu, 2016b). In both studies, it was presumed that FRN would reflect motivational hierarchies and that these hierarchies would be consistent with the generally collectivistic nature of Chinese culture (e.g., FRN in the self and parent condition would be expected to be similar in magnitude, reflecting perceptions of the self and a parent as equal in importance). Consistent with this hypothesis, one study demonstrated that FRN when gambling for a parent was enhanced relative to FRN in the friend condition, and FRN in the friend condition was enhanced relative to the stranger condition. However, both studies produced the unexpected finding that FRN in the self condition was largest in amplitude relative to other relational conditions. A shortcoming of these two studies is that collectivism was assumed based on country of origin. Because collectivism was not directly measured, it is unclear what the field can take away from these studies regarding the association of collectivism and neural response to feedback in a social context, despite this being the aim of the investigations. It is likely that there was considerable variability in neural response to feedback as a function of individual-level cultural views that was not able to be appreciated conceptually or statistically.

Enhanced ERN and FRN are Associated with Social Anxiety

In adult populations, a relationship with a medium effect size (i.e., r=.35) has been observed between ERN and anxiety (Cavanagh and Shackman, 2015; Moser, Moran, Schroder, Donnellan, & Yeung, 2013). Among children, enhanced ERN is thought to be a neural marker of clinical anxiety risk (Meyer, 2017) and specifically shows a link with social anxiety (Kujawa et al., 2016). Age appears to qualify this association, although the evidence is mixed. While systematic review of the literature shows that the strength of the association between anxiety and ERN increases with age (Tamnes et al., 2013), other studies have shown that enhanced ERN is more linked with anxiety among younger youth (Meyer, Weinberg, Klein, & Hajcak, 2012) or identified the absence of an association (Hanna et al., 2012; Eppinger et al., 2009; Richardson et al., 2011). Despite these inconsistencies, the evidence generally supports that the strength of the association between ERN and anxiety increases throughout development, in part attributable to shifts in the phenomenology of fear. Whereas young children might report fears in response to external stimuli (e.g., strangers, the dark), older children and adolescents are thought to experience more internally generated fears (e.g., evaluation and performance concerns). Because internally generated threat is more strongly linked with response-monitoring and concern for one's own behavior than are fears related to external stimuli, the robustness of the association between ERN and anxiety is presumed to correspond with this developmental shift in responsivity to fear-related cues (Meyer, 2017; Weinberg et al., 2016).

Most research that attempts to clarify how developmental changes in socio-affective circuitry during adolescence map onto increased vulnerability for social anxiety have focused on attentional threat processing systems involving the amygdala. However, more recently there has been growing empirical support for heightened neural activation in appetitive-motivational systems and abnormalities in networks involving reward processing as risk factors for SAD (Bar-

Haim et al., 2009; Becker, Simon, Miltner, & Straube, 2017; Caouette & Guyer, 2014; DeVido et al., 2009; Hardin et al., 2007; Lahat et al., 2012; Paulus & Yu, 2012; Perez-Edgar et al., 2013; Silk et al., 2012; Voegler et al., 2019). Although limited, ERP research has produced several relevant findings. In an undergraduate sample, individuals with SAD showed an enhanced FRN following positive social feedback (Cao, Gu, Bi, Zhu, & Wu, 2015) and among adolescents, there was a larger difference in FRN amplitude between rejection and acceptance feedback trials among adolescents as social anxiety increased (Kessel et al., 2015; Kujawa, Arfer, Klein, & Proudfit, 2014). As seen with the ERN, there is evidence that FRN varies as a function of development, with larger FRN amplitudes observed among adolescents than among adults (Hämmerer et al., 2011; Zottoli & Grose-Fifer, 2012). However, it has not been examined if age moderates the association of FRN and anxiety. Overall, the evidence supports the conceptualization of FRN as a neural correlate of social processing that is complementary to the ERN and is relevant to an investigation of social anxiety risk during adolescence.

Study Rationale

In general, humans perceive errors and negative feedback to be threatening, and such events typically elicit aversion and/or distress (Spunt, Lieberman, Cohen, & Eisenberger, 2012). However, there is considerable variability in the degree of threat sensitivity across individuals. That is, an error or negative feedback that occurs in a certain context may be more meaningful depending on the beliefs and characteristics of a person (Weinberg, Riesel, & Hajcak, 2012). Thus, factors such as an individual's cultural values could influence his/her neural response to threat. As such, individuals who endorse a collectivistic worldview may view the consequences of errors or feedback *in a social context*– for example, errors made while part of a team and negative social feedback such as peer rejection– as more catastrophic than do individuals with an individualistic worldview. For collectivistic individuals, the outcome of errors such as a social violation or negative feedback from socially salient others may be perceived to be highly detrimental (e.g., disrupt group cohesion or rupture an interpersonal relationship) and increase motivation to prevent these experiences from occurring. This high level of social threat sensitivity results in upregulation of self-monitoring and neural reactivity to negative feedback.

Project Goals and Study Design

The goal of this study is to determine the extent to which individual differences in adolescents' endorsement of collectivism interact with neural manifestations of error-monitoring and feedback response (i.e., ERN and FRN) occurring in a social context, and the magnitude of the association of these ERP components with social anxiety severity. This research may reveal associations that enrich etiological models of social anxiety. Ultimately, findings could be built upon to elucidate factors that contribute to differences in developmental trajectories, ranging from successful transition into adulthood to onset of psychopathology, and in doing so, improve understanding of how to match treatments and individuals in an effort to reduce disparities (National Institute of Mental Health, 2015)

The project includes three tasks each with a manipulation of social context. The first task takes a replication/extension approach to previous investigations in the field of psychophysiology that have evaluated whether collectivism, a cultural value that represents emphasis on interpersonal relationships, influences the salience of errors made in a social context. Specifically, the notion that facial cues may prime a collectivistic individual's sense of social-evaluative threat has been examined. The literature examining this face priming effect has primarily involved Asian and Asian American samples. As a result, this phenomenon has not been investigated in Latinx samples, a group that also generally endorses high levels of collectivism and social anxiety symptoms. The flanker task used by Park and Kitayama (2014) to examine the impact of face priming on the ERN as a function of collectivism was adapted for use in the present study. Some developmentally-informed changes to the task were made. Most notably, images of adolescents of varying affect (i.e., happy, neutral, and angry expressions) taken from a standardized facial stimuli set (Egger et al., 2011) were included as priming stimuli in lieu of the schematic neutral facial stimuli used by Park and Kitayama (2014).

A second speeded response task was included in the study to examine the impact of social context on error monitoring. This task was included because the first task included a novel design element (i.e., adolescent-aged affective facial stimuli as priming cues), and the adapted flanker paradigm has not been tested in Latinx adult or youth samples. The Zoo Game is a go/no-go task that has been used extensively in youth samples (e.g., Grammer, Carrasco, Gehring, & Morison, 2014; Moser, Fisher, Hicks, Zucker, & Durbin, 2018). In the present study, an ecologically valid manipulation of social context that more directly tapped the construct of collectivism, namely a team condition, was included in lieu of a facial prime along with a comparison individual condition. It was particularly important to select a complementary speeded response task that is known to elicit the ERN in youth samples because the ERN does not reach adult-like levels until late adolescence (Davies, Segalowitz, & Gavin, 2004), and thus, it was possible that the flanker paradigm might not produce the robust effects seen with adults.

Inclusion of the final task was motivated by cultural and developmental research that suggests feedback response is highly relevant to both collectivistic and adolescent samples, with strong response to social feedback seen in both groups. This task, called the "Island Getaway" task (Kujawa et al., 2014), consists of a computerized paradigm designed to elicit the FRN in response to social feedback, namely peer acceptance and rejection. It improves upon existing paradigms commonly used to measure reactivity to social feedback in fMRI research by including elements of direct and mutual peer communication in order to better evoke neural activity related to experiences of peer acceptance/rejection.

Project Aims and Hypotheses

Aim 1

The first aim of the present study is to replicate the face priming effect on ERN magnitude in new cultural and development groups in order to extend the literature examining how collectivism influences the impact of social context on error-monitoring.

Hypothesis 1a. It is hypothesized that higher scores on a self-report measure of collectivism will correspond with enhanced ERN in the angry face primed condition (i.e., a negative association between collectivism and ERN_{Angry} will be observed).

Hypothesis 1b. It is predicted that higher collectivism scores will be associated with more differentiation between ERN in the angry face primed condition and ERN in the control condition (i.e., a negative association between collectivism and $ERN_{Control}$ - ERN_{Angry} will be observed).

Hypothesis 1c. Race/ethnicity is predicted to moderate the associations of collectivism with ERN in the angry face primed condition and its corresponding difference score from the control condition such that these associations will be more negative for Latinx and Asian adolescents than for NLW adolescents.

Aim 2

The second study aim is to identify the influence of the interaction of collectivism and a developmentally-appropriate manipulation of social context on neural response to error.

Hypothesis 2a. It is hypothesized that higher scores on a self-report measure of collectivism will be associated with enhanced ERN in the team condition (i.e., a negative association between collectivism and ERN_{Team} will be observed).

Hypothesis 2b. Collectivism is not anticipated to show an association with ERN in the individual condition.

Hypothesis 2c. Higher collectivism scores are expected to be associated with more differentiation between ERN in the team condition and ERN in the individual condition (i.e., a negative association between collectivism and $ERN_{Individual}$ - ERN_{Team} will be observed).

Hypothesis 2d. Race/ethnicity is predicted to moderate the associations of collectivism with ERN_{Team} and its corresponding difference score from $ERN_{Individual}$ such that these associations will be more negative for Latinx and Asian adolescents than for NLW adolescents.

Aim 3

The third study aim is to identify cultural influences on neural response to social feedback.

Hypothesis 3a. It is hypothesized that higher scores on a self-report measure of collectivism will be associated with enhanced FRN following rejection feedback (i.e., a negative association between collectivism and FRN_{Reject} will be observed).

Hypothesis 3b. Higher collectivism scores are expected to be associated with greater differentiation between FRN following acceptance feedback and FRN following rejection feedback (i.e., a negative association between collectivism and FRN_{Accept} - FRN_{Reject} will be observed).

Hypothesis 3c. Race/ethnicity will moderate the associations of collectivism with FRN following rejection feedback and its corresponding difference score from FRN following acceptance feedback such that these associations will be more negative for Latinx and Asian adolescents than for NLW adolescents.

Aim 4

The fourth aim is to characterize variation in neural response to error in a social context and social feedback as a function of social anxiety.

Hypothesis 4a. Greater social anxiety is hypothesized to be associated with enhanced neural response to errors in the angry face primed condition and a larger difference score from the control condition (i.e., a negative association between social anxiety and ERN_{Angry}/$ERN_{Control}$ - ERN_{Angry} will be observed).

Hypothesis 4b. Greater social anxiety is hypothesized to be associated with enhanced neural response to errors in the team condition and a larger difference score from the individual condition (i.e., a negative association between social anxiety and ERN_{Team}/$ERN_{Individual}$ - ERN_{Team} will be observed).

Hypothesis 4c. Greater social anxiety is hypothesized to be associated with enhanced neural response to rejection feedback and a larger difference score from acceptance feedback (i.e., a negative association between social anxiety and FRN_{Reject}/FRN_{Accept} - FRN_{Reject} will be observed).

Hypothesis 4d. Race/ethnicity will moderate the association of social anxiety and ERP components elicited in a socially salient context (i.e., ERN_{Angry}, ERN_{Team}, FRN_{Reject}), such that these associations will be more negative for Latinx and Asian adolescents than for NLW adolescents.

Hypothesis 4e. Collectivism will moderate the association of social anxiety and ERP components elicited in a socially salient context (i.e., ERN_{Angry}, ERN_{Team}, FRN_{Reject}), such that these associations will be more negative among adolescents who endorse higher collectivism scores.

Method

Participants

Participants were 108 adolescents (ages 13-17) recruited from Los Angeles County. Recruitment was conducted through several avenues. This included distribution of informational materials at middle and high school open house events, community gatherings (e.g., health fairs), churches, libraries, recreational centers, and UCLA campus tours for prospective students. Adolescents were also made aware of the study through partnerships with organizations such as the Girl Scouts and the Boys and Girls Club. A number of parents were reached through online postings on Facebook and neighborhood-based forums such as Nextdoor. Some adolescents were referred by previous participants, although first-degree relatives were excluded from participating. Compensation was provided for time and travel.

Exclusion criteria were: clinical-level elevation of Attention-Deficit/Hyperactivity (ADHD) symptoms, IQ < 80, and parent-reported diagnosis of Autism Spectrum Disorder. Eligibility was determined via administration of the Youth Self Report (Achenbach, 1991), select subtests of the Weschler Abbreviated Scales of Intelligence (Wechsler, 1999), and a brief review of youth psychiatric history with parent. This was to ensure that youth enrolled in the study were able to appropriately attend to the tasks and were responsive to social cues as conveyed via facial stimuli, as well as to reduce potential confounds in electrophysiological measures related to cognitive control. Following study enrollment, six participants were excluded after screening due to clinically elevated ADHD symptoms.

In total, 102 participants completed the computerized EEG tasks. The overall sample was 47.0% male, 51.0% female, and 2.0% other and with an average age of 15.14 years (*SD*=1.37). The sample was comprised of Latinx (40.20%), NLW (40.20%), and Asian (19.60%) adolescents. Per 2018 U.S. Department of Housing and Urban Development guidelines for Los Angeles County, 34.3% of families were considered low-income based on parent-reported annual family income and number of individuals in the household (85.7% of which were Latinx). Per the U.S. Department of Health and Human Services Federal Poverty Guidelines, 12.7% of families fell below the federal poverty line (92.3% of which were Latinx).

Measures

Demographics. Age, gender, and race/ethnicity were collected via a standard demographic form. Parents provided an estimate of annual family income by selecting from the following ranges of earnings per year: 1) less than $10,000, 2) $10-20,000, 3) $20-30,000, 4) $30-50,000, 5) $50-75,000, 6) $75-100,000, 7) $100-125,000, 8) $125-150,000, 9) $150-200,000, or 10) Over $200,000. Parents additionally reported how many individuals were supported by this income. Using this information, families were categorized as low-income or not low-income using guidelines put forth by the U.S. Department of Housing and Urban Development.

Self-construal. Collectivism was measured using the Individualism-Collectivism Scale (Triandis & Gelfand, 1998), a 16-item measure. The measure was originally validated in a racially/ethnically heterogeneous sample of undergraduates and showed good internal consistency and convergence with other measures related to self-construal (Triandis & Gelfand, 1998). This measure has been used in several studies to examine the association between ratings of collectivism and anxiety severity in Latinx youth (Varela et al., 2004; Varela, Sanchez-Sosa, Biggs, & Luis, 2009). Further, in a sample of Latinx adolescents, internal consistency of the measure's subscales was fair with Cronbach's alpha of 0.79 for the collectivism dimension and 0.73 for the individualism dimension (Lorenzo-Blanco et al., 2015).

Social anxiety. The Social Anxiety Scale for Adolescents (SAS-A) (La Greca & Lopez, 1998) consists of 22-items and produces three subscales: Fear of Negative Evaluation, Social Avoidance and Distress-New (avoidance and distress in response new situations or unfamiliar peers), and Social Avoidance and Distress-General (avoidance and distress experienced generally with peers). Internal consistency for the three subscales has been found to be excellent to fair with Cronbach's alpha of 0.91, 0.83, and 0.76, respectively. The measure has been validated in a Latinx adolescent sample (La Greca, Ingles, Lai, & Marzo, 2015). In the present study, a cut-off score of 53 (representing the top 25th percentile of scores) was used to indicate clinically-elevated social anxiety.

Experimental Tasks

Flanker. The flanker task, adapted from Park and Kitayama (2014), consisted of eight blocks of 56 trials. Each trial included presentation of a priming stimulus followed by a set of five arrows. Participants were instructed to press a game controller button that corresponded with the direction of the central arrow. Within each block, participants were presented with an equal number of trials of four arrowhead sequences (i.e., left and right facing central arrows that were either congruent or incongruent with flanking arrows). Prior to the display of each arrowhead sequence, participants were randomly presented with one of seven prime types. Facial primes were taken from the NIMH Child Emotional Faces Picture Set (Egger et al., 2011) and included male and female faces within three affective conditions (i.e., happy, neutral, angry). A house image adopted from Polk et al. (2007) served as a control prime.

In each trial, the priming stimulus was first presented for 90 ms, followed by a fixation cross jittered between 300-400 ms. Next, one of four arrowhead sequences was presented for 100 ms. Participants were able to respond while the arrowheads were displayed or during a blank response slide which was displayed for 800 ms. The inter-trial interval was 800 ms.

Go/no-go. Participants completed a developmentally-appropriate go/no-go task adapted from a paradigm by McDermott and colleagues (2014). In this task, youth are told that they are playing a game in which the goal is to return escaped zoo animals to their cages and to avoid capturing friendly orangutans who are allowed to roam free at the zoo and do not need to be put into a cage. Youth were instructed to press a button as quickly as they could when they saw a zoo animal (go trials) and to inhibit response when they saw an orangutan (no-go trials). In half of the blocks, youth were told that points earned for correct responses went toward a team point goal, meaning that points accumulated in these rounds would be added to the score of a previous participant to reach a certain point goal. If participants reach this team point goal, they were told they would win a shared prize. On the other half of the blocks, youth were told they were earning points toward an individual point goal to win a prize for just themselves.

First, participants completed a brief practice block of 12 trials, which included nine go trials and three no-go trials. Then, youth completed eight blocks of 40 trials which included 30 go trials and 10 no-go trials, for a total of 320 trials. All of the go trial stimuli were novel. Blocks were evenly split between the individual and team conditions. Each trial began with a fixation cross presented for 300 ms followed by the stimulus presented for 500 ms. A blank screen was then displayed for 500 ms. Youth were able to provide a response at any point while the stimulus or blank screen were displayed. Stimuli in each block were balanced with respect to color, animal type, and size.

Social feedback. Participants completed a computerized social feedback task adapted from the "Island Getaway" paradigm developed by Kujawa and colleagues (2014). At the start of the game, participants were informed that they would be voting in rounds of a draft to see who made it onto a final team of six teenagers from a group of 12. Participants were told that those who made it through all rounds of draft without being voted out would play a team game, otherwise the participant would play the same game but by themselves. A player profile was created for the youth which included basic demographic information (i.e., first name, age, gender, hometown, name of school, and main hobby) as well as a photograph that was taken by the experimenter at the start of the study visit. Players participated in six voting rounds in which they were presented with several different co-player profiles. The co-player profiles included five male profiles and six female profiles, with ages ranging from 13-17 years. Photographs for the co-player profiles were taken from the NIMH Child Emotional Faces Picture Set (Egger et al., 2011). After casting a vote, players were presented with a fixation cross jittered between 2000-3000 ms, followed by the co-player's profile again for 2000 ms. Prior to receiving feedback, a fixation cross was displayed for 1000 ms, followed by either a thumbs up or thumbs down image for 1500 ms, representing acceptance or rejection, respectively.

Participants completed six voting rounds, with one co-player randomly removed each round. Between rounds, the participant was asked to answer a free-response poll question (e.g., "What is your least favorite activity?") that was then added to his or her profile. The participant was also shown each co-player's response. In total, the participant completed 51 feedback trials evenly split between acceptance and rejection trials, with the last trial determined randomly.

Electrophysiological Data Recording and Reduction

EEG recordings were obtained using a BioSemi ActiveView ActiveTwo system with an elastic cap containing 64 Ag/AgCl scalp electrodes. The electrooculogram was recorded by placing two electrodes near the outer canthi of both eyes and two electrodes above and below the right eye. Two electrodes were placed on left and right mastoids. Data were recorded referenced to a driven right leg passive electrode and common mode sense active electrode and re-referenced offline to that average of all head electrodes, in line with published recommendations (Dien, 2017). All impedances were maintained below 30 kΩ. Data were digitized at 1024 Hz with filters set from 0.16-100 Hz.

Following an initial screen for extreme artifacts, the continuous EEG was segmented into 200 ms epochs. Epochs were inspected for gross artifact using an automated algorithm that rejected individual sweeps in which (a) the absolute difference between two sampling points exceeded 50 μV, (b) the absolute voltage range for any individual electrode exceeded 300 μV, (c) amplitude exceeded 150 μV or fell below -150 μV, and/or (d) sustained activity less than 0.5 μV within a 100 ms interval had occurred. Ocular artifacts were corrected using the algorithm described by Makeig, Bell, Jung, and Sejnowski (1996). Waveforms presented in Figures 1-4 and Figure 7 were filtered with a Butterworth zero phase 0.1-30 Hz bandpass filter.

In line with previous literature using youth samples, the ERN and CRN were quantified using mean amplitude measures relative to a pre-response baseline of -300 to -100 ms. ERN mean amplitude was computed on error trials in a window of 100 ms following response. The CRN was computed similarly but using correct trials. Because raw ERN measures include processes common to both errors and correct responses, a difference wave was created by subtracting neural response on correct trials from neural response on error trials (i.e., ERN minus CRN), which is referred to as the ΔERN. The ΔERN is thought to be a more developmentally-appropriate reflection of error monitoring processes among youth (Grammer et al., 2014; Torpey et al., 2012), and as such, it is used as the outcome measure in all primary analyses involving ERN.

Based on visual inspection of grand average waveforms and previous reports in comparable youth samples, neural response to rejection and acceptance were quantified using mean amplitude measures relative to a pre-stimulus baseline of 100 ms prior to onset of feedback stimulus. The mean amplitude of the FRN was computed separately for acceptance and rejection feedback in a window 200-300 ms following onset of stimuli.

Data Analytic Strategy

Repeated measures ANOVAs were used to confirm the presence of the ERP components (i.e., ERN, FRN). Group differences in ERP mean amplitude and difference score measures, as well as in reaction time and accuracy, were assessed using one-way ANOVAs. Post-hoc analyses of significant interactions utilized paired samples t-tests. Effect sizes were calculated using G*Power 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009).

To test hypotheses that collectivism is related to ERP measures in a social context and that this association is moderated by race/ethnicity, parallel linear regressions were conducted to produce the conditional effect of collectivism on the ERP measure for each racial/ethnic group. The same regression approach was used to examine the association of social anxiety with ERP outcomes, with race/ethnicity and collectivism as moderators. Regressions were conducted using the PROCESS macro (Hayes, 2017) for SPSS 25.

Moderator and covariates selection. Across all tasks, the project included examination of race/ethnicity as a moderator of proposed associations. Research supports that even in the absence of differences in behavioral outcomes between groups, there may still be heterogeneity at the neural level, suggesting that cognitive processes are not necessarily supported by common neural networks across groups (Gatze-Kopp, 2016; Kim & Sasaki, 2014). As such, racial/ethnic group was included as a moderator to ensure that associations were not obscured in a diverse adolescent sample.

Theoretical concerns and statistical measures were taken into consideration when selecting covariates for inclusion in primary regression analyses. First, variables that demonstrated a well-established relationship with the dependent variable (DV) in the literature were included in models (e.g., age (covariate) with ERN and social anxiety (DVs) (Meyer, 2017; Meyer et al., 2012; Tamnes et al., 2013; Weinberg et al., 2016)). Other variables were considered as covariates if racial/ethnic groups or the predictor/DV varied as a function of this factor, especially since racial/ethnic groups were not matched on demographics. Inclusion of these variables were guided by use of residual plots. An attempt was made to identify the simplest model that produced random distribution of residuals (Zellner, 2001).

Results

Overall Sample Characteristics

Relevant descriptive statistics for the overall sample are summarized in Table 1. One-way ANOVAs showed group differences in collectivism and social anxiety based on race/ethnicity, age, gender, and low-income status.

Ratings of collectivism varied by race/ethnicity and low-income status, $F(2,99)=7.16$, $p=.001$, $F(1,99)=14.04$, $p<.0001$, respectively. As anticipated, Latinx and Asian adolescents endorsed more collectivism than NLW adolescents, Latinx vs. NLW: $t(80)=-3.58$, $p=.001$, $d=.79$, Asian vs. NLW: $t(59)=-2.26$, $p=.02$, $d=.60$. Similarly, low-income adolescents endorsed more collectivism than their respective counterparts.

Social anxiety severity ratings also varied by race/ethnicity, age, gender, and low-income status, $F(2,99)=5.27$, $p=.007$, $F(1,100)=6.52$, $p=.01$, $F(1,100)=12.80$, $p=.001$, $F(1,99)=10.37$, $p=.002$, respectively. Results indicated that Latinx adolescents endorsed less social anxiety than NLW adolescents, $t(80)=3.19$, $p=.002$, $d=.70$. Compared to their respective counterparts, younger (i.e., 13-14 year old), male, and low-income adolescents additionally endorsed less social anxiety.

Contrary to assumptions that social anxiety severity would be greater as collectivism increased, a bivariate correlation across the full sample revealed a negative association between social anxiety severity and collectivism, $r=-.23$, $p=.02$. This correlation was comparable in magnitude when examined separately within each racial/ethnic group, NLW: $d= -.065$; Latinx: $d= -.076$; Asian: $d= -.065$.

Finally, there were no racial/ethnic group differences in gender distribution or age. However, there was a difference between racial/ethnic groups by low-income status, $\chi^2=46.13$, $df=2$, $p<.0001$, such that low-income adolescents were predominately Latinx (85.7%). Race/ethnicity and low-income status were found to be strongly related, $\phi_c = .68$, $p<.0001$.

Table 1

Means and Standard Deviations of Continuous Self-report Variables

Construct	Full sample *M(SD)* *N = 102*	NLW *M(SD)* *n = 41*	Latinx *M(SD)* *n = 41*	Asian *M(SD)* *n = 20*
Collectivism	55.30(9.96)	51.05(10.66)$^{*+}$	58.61(8.32)*	57.25(8.66)$^{+}$
Individualism	46.03(9.14)	44.51(7.69)$^{+}$	45.63(10.15)	50.00(9.00)$^{+}$
Social anxiety	44.67(13.03)	49.29(11.98)*	40.34(13.38)*	44.10(11.70)

Note: M=Mean; SD=Standard deviation; NLW=non-Latinx White; *=groups significantly different, $p<.01$; +=groups significantly different, $p<.05$

Did Speeded Response Tasks Designed to Elicit the ERN Work as Expected?

Confirming the presence of the ERN in the flanker task. As seen in Figure 1, visual inspection of grand-average ERP waveforms reveals an enhanced negative deflection around the time of error commission relative to correct responses at frontal sites along the midline. A repeated measures ANOVA was conducted involving electrode site (FCz, Cz, Pz), response type (error, correct), and condition (happy, neutral, angry, control). Mauchly's Test indicated a violation of the assumption of sphericity, therefore degrees of freedom were reported using Greenhouse-Geisser estimates. The presence of the ERN was confirmed by a main effect of response type which was qualified by a site by response type interaction, such that there was a larger negativity on incorrect trials relative to correct trials at frontocentral sites relative to posterior that was maximal at FCz, $F(1,55)=6.24$, $p=.02$, $\eta_p^2=.10$, $F(1.40, 76.68)=44.59$, $p<.0001$, $\eta_p^2=.45$. Mean amplitude of ERP components varied as a function of condition, $F(2.21,121.71)=5.01$, $p=.006$, $\eta_p^2=.084$. As illustrated by Figure 2, paired samples t-tests showed differences in mean amplitude measures by condition such that ERN in the happy and neutral face primed conditions were more negative than ERN in the control condition, happy vs. control: $t(55)=1.94$, $p=.05$, $d=.26$, neutral vs. control: $t(55)=2.24$, $p=.03$, $d=.30$. ERN in the neutral condition was also shown to be more negative than ERN in the angry condition, $t(55)=-2.11$, $p=.03$, $d=.28$. Overall, it appeared that the task was successful in eliciting an ERN that varied as a function of condition.

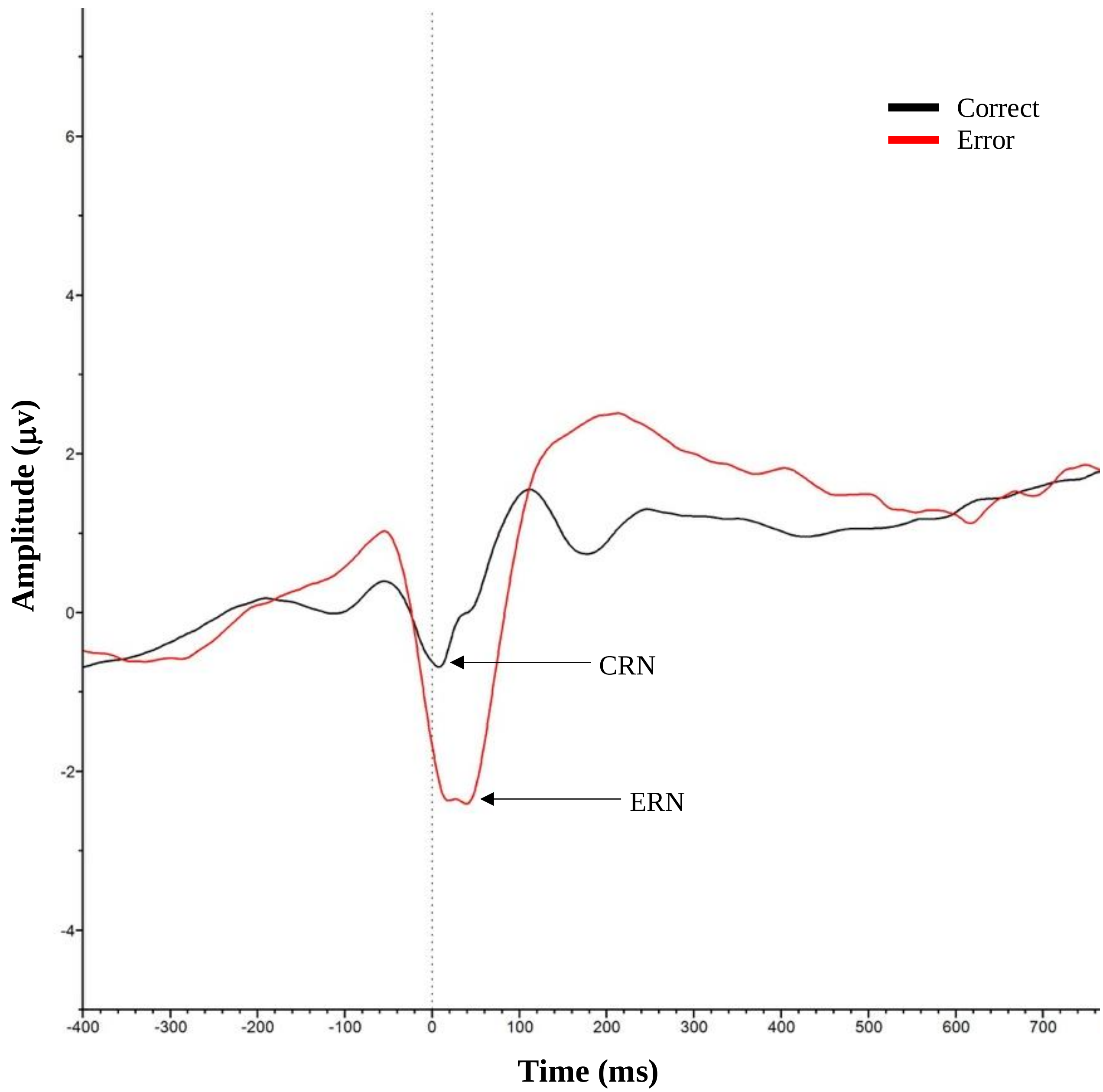

Figure 1. Main effect of response type (error, correct) as illustrated by ERN and CRN elicited by the flanker task at FCz recording site, relative to occurrence of error commission (0 ms).

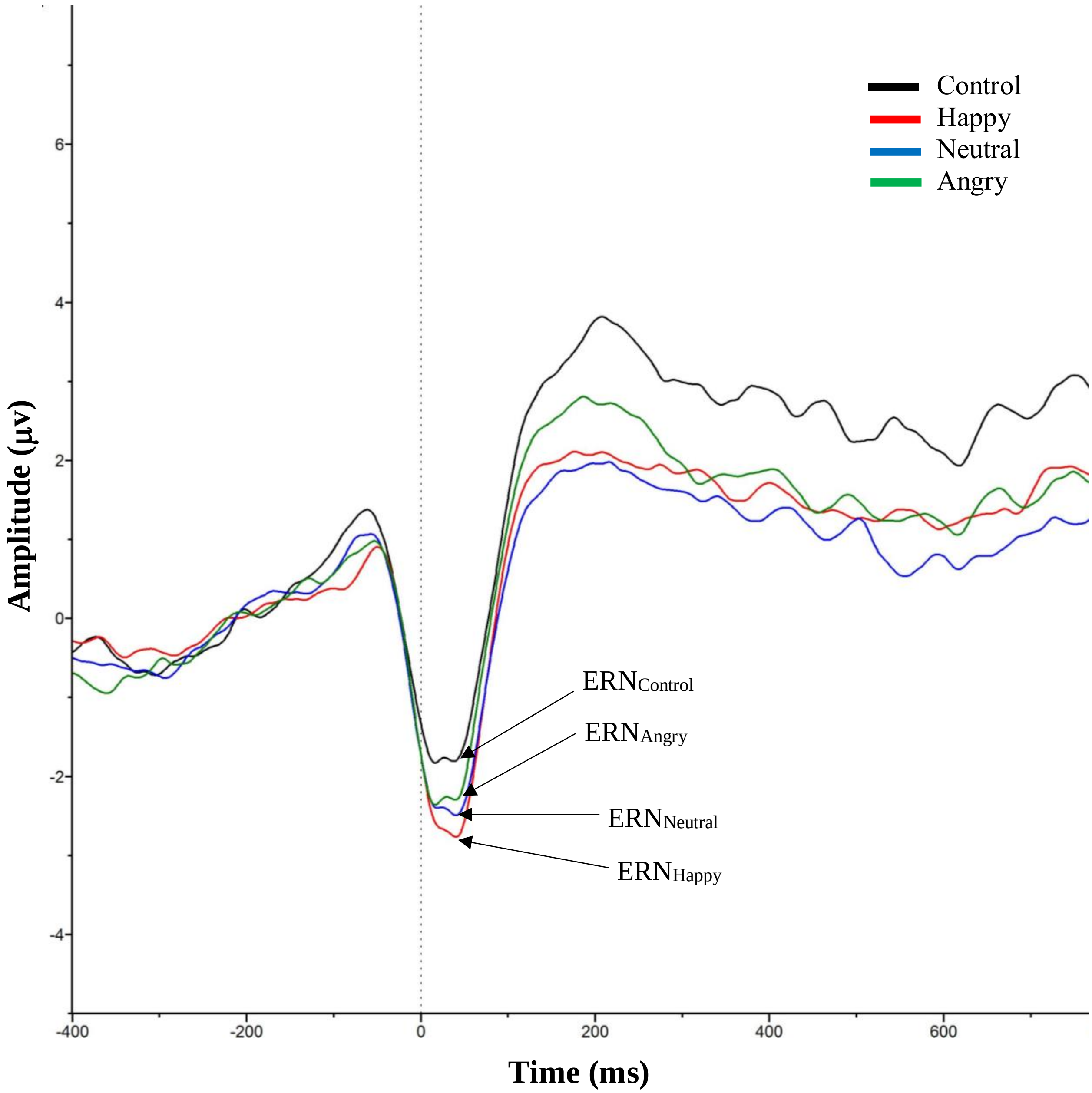

Figure 2. ERN as elicited by the flanker task within each condition at FCz recording site, relative to occurrence of error commission (0 ms).

Mean amplitude measures of ERP components are summarized in Table 2. One-way ANOVAs were used to examine group differences in ERN, CRN, and ΔERN measures based on race/ethnicity, age, gender, clinically-elevated social anxiety, and income. The only group difference that emerged was that low-income adolescents had a less negative ΔERN_{Happy} score relative to adolescents who were not low-income, $F(1,53)=5.04$, $p=.03$.

Table 2

Mean Amplitude Values in Microvolts (μv) of ERP Components Elicited by the Flanker Task at FCz

Condition	Component	Full Sample *M(SD)* *N = 56*	NLW *M(SD)* *n = 23*	Latinx *M(SD)* *n = 22*	Asian *M(SD)* *n = 11*
Control	CRN	.44(1.95)	.22(1.97)	.38(1.88)	.98(2.11)
	ERN	-.97(3.13)	-.74(3.05)	-.78(3.49)	-1.84(2.62)
	ΔERN	-1.41(2.98)	-.96(3.36)	-1.17(3.01)	-2.83(1.54)
Happy	CRN	.28(1.75)	.14(1.57)	.13(1.76)	.84(2.13)
	ERN	-1.64(2.43)	-1.68(1.86)	-1.34(2.88)	-2.16(2.59)
	ΔERN	-1.91(2.26)	-1.82(1.90)	-1.47(2.37)	-3.00(2.55)
Neutral	CRN	.27(1.62)	.16(1.46)	.11(1.61)	.89(1.97)
	ERN	-1.61(2.63)	-1.53(2.23)	-1.38(2.88)	-2.21(3.03)
	ΔERN	-1.88(2.37)	-1.70(1.88)	-1.48(2.57)	-3.05(2.70)
Angry	CRN	.38(1.62)	.28(1.40)	.21(1.64)	.92(2.02)
	ERN	-1.21(2.28)	-.88(2.31)	-1.32(2.25)	-1.70(2.40)
	ΔERN	-1.59(2.13)	-1.16(2.23)	-1.53(1.80)	-2.62(2.36)

Note: M=Mean; SD=Standard deviation; NLW=non-Latinx White; CRN=Correct related negativity; ERN=Error related negativity

Flanker task behavioral performance. Behavioral performance as measured by reaction time and accuracy is summarized in Table 3. Differences in reaction time between conditions (happy, neutral, angry, control) and response type (error, correct) were assessed using repeated measures ANOVA. In all four conditions, adolescents exhibited faster response times on error trials than on correct trials, $F(1,55)=218.19$, $p<.0001$, $\eta^2=.80$. Error and correct responses in the face primed conditions had faster reaction time than in the control condition, $F(3,53)=7.73$, $p<.0001$, $\eta^2=.30$. Paired samples t-tests revealed several differences in reaction time by condition. Reaction time for correct responses in all face primed conditions were faster than correct responses in the control condition, angry vs. control: $t(55)=3.97$, $p<.0001$, $d=.53$, happy vs. control: $t(55)=3.33$, $p=.002$, $d=.45$, neutral vs. control: $t(55)=3.08$, $p=.003$, $d=.41$. Reaction times for errors in the happy face primed and neutral face primed conditions were faster than errors made in the control condition, happy vs. control: $t(55)=2.89$, $p=.0005$, $d=.39$, neutral vs. control: $t(55)=3.22$, $p=.002$, $d=.43$. Reaction time for errors made in the happy and neutral face primed conditions were also faster than errors made in the angry face primed condition, happy vs. angry: $t(55)=-2.23$, $p=.03$, $d=.30$, neutral vs. angry: $t(55)=-3.00$, $p=.004$, $d=.40$.

Accuracy did not appear to vary as a function of condition. One-way ANOVAs showed no differences in reaction time or accuracy based on race/ethnicity, age, gender, clinically-elevated social anxiety, or income.

Participants with fewer than six error trials in a given condition after artifact screening were excluded, in line with previous research (Foti, Kotov, & Hajcak, 2013; Olvet & Hajcak, 2009a; Olvet & Hajcak, 2009b; Pontifex et al., 2010). Participants who demonstrated no better than random performance (>50% incorrect responses) were also excluded. In the flanker task, 23 participants exhibited fewer than six errors in the control condition, 20 participants exhibited fewer than six errors in one or more of the face primed conditions, one participant was excluded due to accuracy, and one participant opted not to complete the task. One participant appeared to be a statistical outlier based on inspection of several indices (e.g., standardized residuals, Cook's

Distance, leverage). Following these exclusions, the final sample size of participants included in analyses was 56.

Table 3

Behavioral Performance in the Flanker Task

Condition	Response	Full sample *M(SD)* *N = 56*		NLW *M(SD)* *n = 23*		Latinx *M(SD)* *n = 22*		Asian *M(SD)* *n = 11*	
		RT (ms)	Acc (%)	RT (ms)	Acc (%)	RT (ms)	Acc (%)	RT (ms)	Acc (%)
Happy	Error	166.61	79.47	166.14	80.83	171.01	76.26	158.78	83.03
		(53.16)	(11.47)	(44.34)	(11.49)	(67.92)	(13.11)	(37.64)	(5.54)
	Correct	246.37		255.30		245.38		229.68	
		(57.97)		(58.58)		(67.61)		(28.97)	
Neutral	Error	164.89	79.11	164.31	80.32	170.65	77.23	154.58	80.34
		(51.13)	(12.87)	(39.00)	(13.79)	(68.41)	(14.03)	(31.81)	(8.16)
	Correct	245.82		256.78		241.82		230.89	
		(60.58)		(60.55)		(71.16)		(30.48)	
Angry	Error	174.38	79.72	175.29	80.74	181.73	77.86	157.75	81.30
		(54.55)	(12.68)	(46.36)	(13.19)	(69.89)	(14.59)	(30.93)	(6.49)
	Correct	245.86		255.60		245.55		226.77	
		(59.06)		(61.87)		(66.51)		(28.76)	
Control	Error	176.94	80.01	181.71	80.08	178.14	78.45	164.55	82.99
		(59.44)	(11.22)	(47.47)	(11.91)	(77.38)	(12.15)	(40.95)	(7.47)
	Correct	253.61		260.71		155.22		235.50	
		(64.08)		(69.10)		(69.66)		(37.44)	

Note: M=Mean; SD=Standard deviation; NLW=non-Latinx White; RT=reaction time; Acc=accuracy; ms=milliseconds

Confirming the presence of the ERN in the go/no-go task. As seen in Figures 3-4, visual inspection of grand-average ERP waveforms revealed an enhanced negative deflection around the time of error commission relative to correct response at frontal sites along the midline. The presence of an ERN was assessed using a repeated measures ANOVA involving electrode site (FCz, Cz, Pz), response type (error, correct) and condition (team, individual). Mauchly's Test indicated a violation of the assumption of sphericity, therefore degrees of freedom were reported using Greenhouse-Geisser estimates. Main effects of response type and site showed greater negativity on error trials relative to correct trials at frontocentral sites relative to parietal, $F(1,89)=69.22$, $p<.0001$, $\eta_p^2=.44$, $F(1.34,119.13)=212.45$, $p<.0001$, $\eta_p^2=.71$, respectively, such that negativity of error trials relative to correct trials differed as a function of electrode site with greater negativity at frontal relative to posterior sites, $F(1.20,107.22)=54.59$, $p<.0001$, $\eta_p^2=.38$. Paired-samples t-tests showed that mean amplitude of the ERN at FCz in both team and individual conditions was more negative than at Cz, suggesting that the ERN was maximal at FCz, team: $t(89)=-11.87$, $p<.0001$, $d=1.18$; individual: $t(89)=-11.42$, $p<.0001$, $d=1.13$. ERP measures in each condition varied as a function of site, $F(1.47, 130.83)=5.41$, $p=.01$, $\eta_p^2=.057$. Results suggest that the go/no-go task elicited an ERN as anticipated.

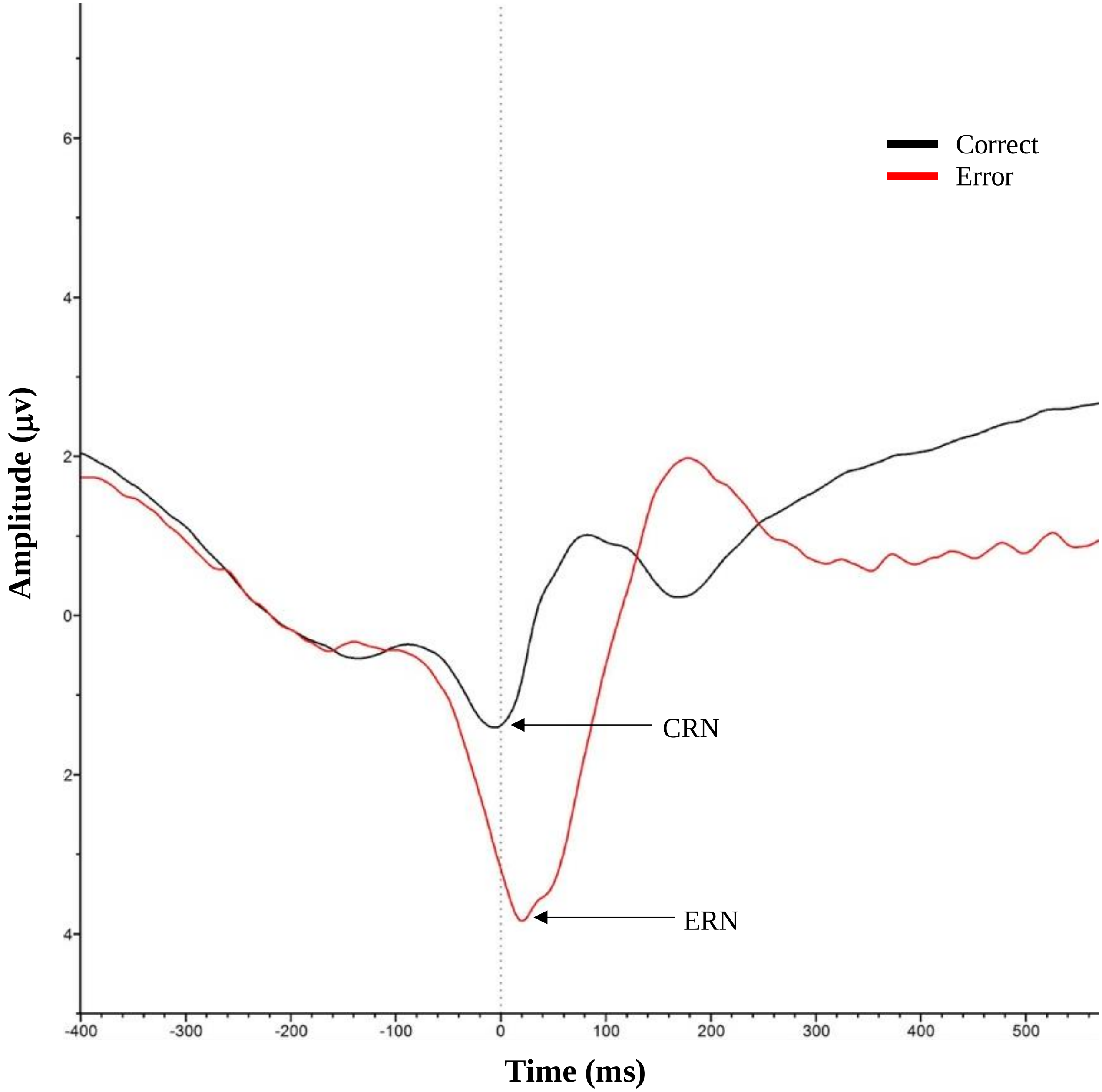

Figure 3. ERN and CRN in the individual condition as elicited by the go/no-go task at FCz recording site, relative to occurrence of error commission (0 ms).

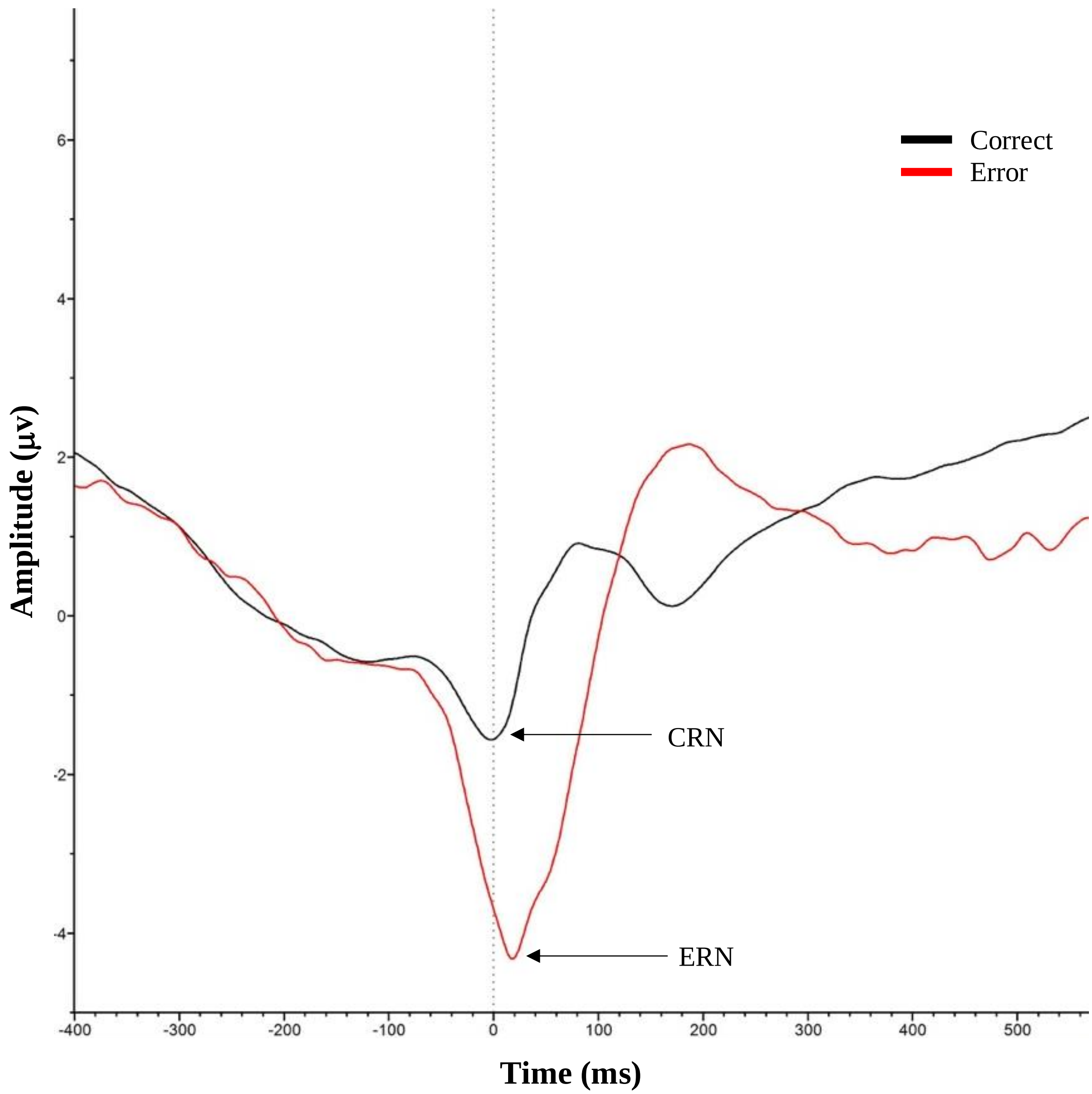

Figure 4. ERN and CRN in the team condition as elicited by the go/no-go task at FCz recording site, relative to occurrence of error commission (0 ms).

Mean amplitude measures of ERP components are summarized in Table 4. One-way ANOVAs revealed no group differences by race/ethnicity, age, gender, clinically-elevated social anxiety, or income.

Table 4

Mean Amplitude Values in Microvolts (μv) of ERP Components Elicited by the Go/no-go Task at FCz

Condition	Component	Full Sample *M(SD)* *N = 90*	NLW *M(SD)* *n = 40*	Latinx *M(SD)* *n = 35*	Asian *M(SD)* *n = 15*
Individual	CRN	-.79(1.57)	-.91(1.69)	-.75(1.60)	-.59(1.20)
	ERN	-2.89(2.40)	-2.60(2.38)	-3.16(2.61)	-3.05(1.95)
	ΔERN	-2.10(2.42)	-1.69(2.61)	-2.41(2.37)	-2.46(1.98)
Team	CRN	-.94(1.63)	-.98(1.78)	-.84(1.44)	-1.06(1.71)
	ERN	-3.27(2.65)	-3.10(2.5)	-3.21(2.69)	-3.88(3.01)
	ΔERN	-2.33(2.54)	-2.11(2.42)	-2.37(2.78)	-2.82(2.34)

Note: M=Mean; SD=Standard deviation; NLW=non-Latinx White; CRN=Correct related negativity; ERN=Error related negativity

Go/no-go task behavioral performance. Accuracy and reaction time on error and correct trials are summarized in Table 5. Of note, two participants had missing task performance data due to a technical error during recording.

A repeated measures ANOVA confirmed differences in response time by response type (error, correct) and condition (team, individual). As seen in the flanker task, responses were faster on error trials than on correct trials, $F(1, 87)=601.24$, $p<.0001$, $\eta^2=.87$. Additionally, there was a main effect of condition such that responses in the individual condition were faster than in the team condition, $F(1, 87)= 6.73$, $p=.01$, $\eta^2=.072$.

There were racial/ethnic group differences in reaction time for correct responses in both conditions and error responses in the team condition, $F(2,85)=5.26$, $p=.007$, $F(2,85)=4.24$, $p=.02$, $F(2,85)=5.19$, $p=.007$, respectively. Independent samples t-tests revealed that NLW and Latinx adolescents did not differ in reaction time. Latinx adolescents demonstrated slower reaction time across conditions and response type than Asian adolescents, team correct: $t(53)=3.49$, $p=.001$, $d=.99$, individual correct: $t(53)=3.13$, $p=.003$, $d=.86$, team error: $t(53)=2.85$, $p=.006$, $d=.86$. NLW adolescents also demonstrated slower response times than Asian adolescents, team correct: $t(53)=3.05$, $p=.003$, $d=.94$, individual correct: $t(53)=2.88$, $p=.006$, $d=.87$, team error: $t(53)=3.23$, $p=.002$, $d=.97$. Group differences in accuracy based on psychopathology emerged as well, such that adolescents who endorsed clinically-elevated social anxiety made more errors in both conditions, team: $F(1,86)=6.20$, $p=.01$, individual: $F(1,86)=8.85$, $p=.004$.

Eleven participants were excluded from analyses due to insufficient number of error trials in one or both conditions. One participant appeared to be a statistical outlier based on inspection of several indices (e.g., standardized residuals, Cook's Distance, leverage). Following these exclusions, the final sample size of participants included in analyses was 90.

Table 5

Behavioral Performance in the Go/No-go Task

Condition	Response	Full sample *M(SD)* *N = 88*		NLW *M(SD)* *n = 39*		Latinx *M(SD)* *n = 34*		Asian *M(SD)* *n = 15*	
		RT (ms)	% error on No-go trials	RT (ms)	% error on No-go trials	RT (ms)	% error on No-go trials	RT (ms)	% error on No-go trials
Team	Error	293.03 (28.97)	30.59 (11.14)	298.80 (28.24)$^{+}$	31.41 (11.45)	295.54 (27.60)*	29.70 (10.14)	272.32 (26.25)$^{*+}$	30.50 (12.99)
	Correct	327.61 (25.56)		331.53 (26.11)$^{+}$		331.32 (23.54)*		209.00 (21.35)$^{*+}$	
Individual	Error	288.61 (27.36)	31.84 (11.24)	292.44 (31.02)	32.69 (11.67)	287.58 (24.01)	32.72 (10.19)	280.97 (23.98)	27.66 (12.15)
	Correct	323.02 (26.34)		326.68 (25.94)$^{+}$		326.51 (26.16)*		305.62 (21.89)$^{*+}$	

Note: M=Mean; SD=Standard deviation; NLW=non-Latinx White; RT=reaction time; ms=millisecond; *=groups significantly different, p<.01; +=groups significantly different, p<.01

Collectivism and Neural Response to Error in a Social Context

Collectivism and ERN following face priming in the flanker task. In line with Aim 1 to replicate the face priming effect on the ERN, two regression models were run with ΔERN_{Angry} and $\Delta ERN_{Control}$ - ΔERN_{Angry} as outcomes. It was hypothesized that higher collectivism scores would be associated with enhanced ERN in the angry face primed condition (Hypothesis 1a) and greater differentiation between ERN in the angry face primed condition and ERN in the control image primed condition (Hypothesis 1b). In each regression model, collectivism was included as the predictor and race/ethnicity as a moderator in order to test the hypothesis that associations would be more negative for Latinx and Asian adolescents (Hypothesis 1c). Age was included as a covariate.

Contrary to predictions, collectivism did not demonstrate an association with ΔERN_{Angry} or $\Delta ERN_{Control}$ - ΔERN_{Angry}, and race/ethnicity did not demonstrate a moderating effect.

Collectivism and ERN in the team condition as elicited by the go/no-go task. In line with Aim 2 to identify the influence of the interaction of collectivism and a developmentally-appropriate manipulation of social environment on ERN, three parallel linear regressions were conducted using ΔERN_{Team}, $\Delta ERN_{Individual}$, and $\Delta ERN_{Individual}$ - ΔERN_{Team} as outcomes. Each model contained collectivism as the predictor and race/ethnicity as a moderator, with age included as a covariate.

The first regression model was set up to test the hypothesis that higher collectivism scores would be associated with enhanced ΔERN_{Team} (Hypothesis 2a) and that race/ethnicity would moderate this association (Hypothesis 2d). The overall model accounted for 14.61% of the variance in ΔERN_{Team}, $F(6,83)=2.36$, $p=.03$. Race/ethnicity interacted with collectivism in predicting ΔERN_{Team}, $F(2,83)=6.50$, $p=.002$. Probing of this interaction revealed conditional effects illustrated in Figure 5 such that as collectivism increased, NLW adolescents differentiated less between error and correct responses in the team condition and Latinx adolescents differentiated more, NLW: $\beta=.10$, $p=.009$, Latinx: $\beta=-.12$, $p=.02$. This model provided support for the hypothesis that higher collectivism scores would be associated with enhanced ERN in the team condition and that this effect would be more pronounced for Latinx adolescents. However, results regarding the association between collectivism and attenuated ERN in the team condition for NLW adolescents were unanticipated.

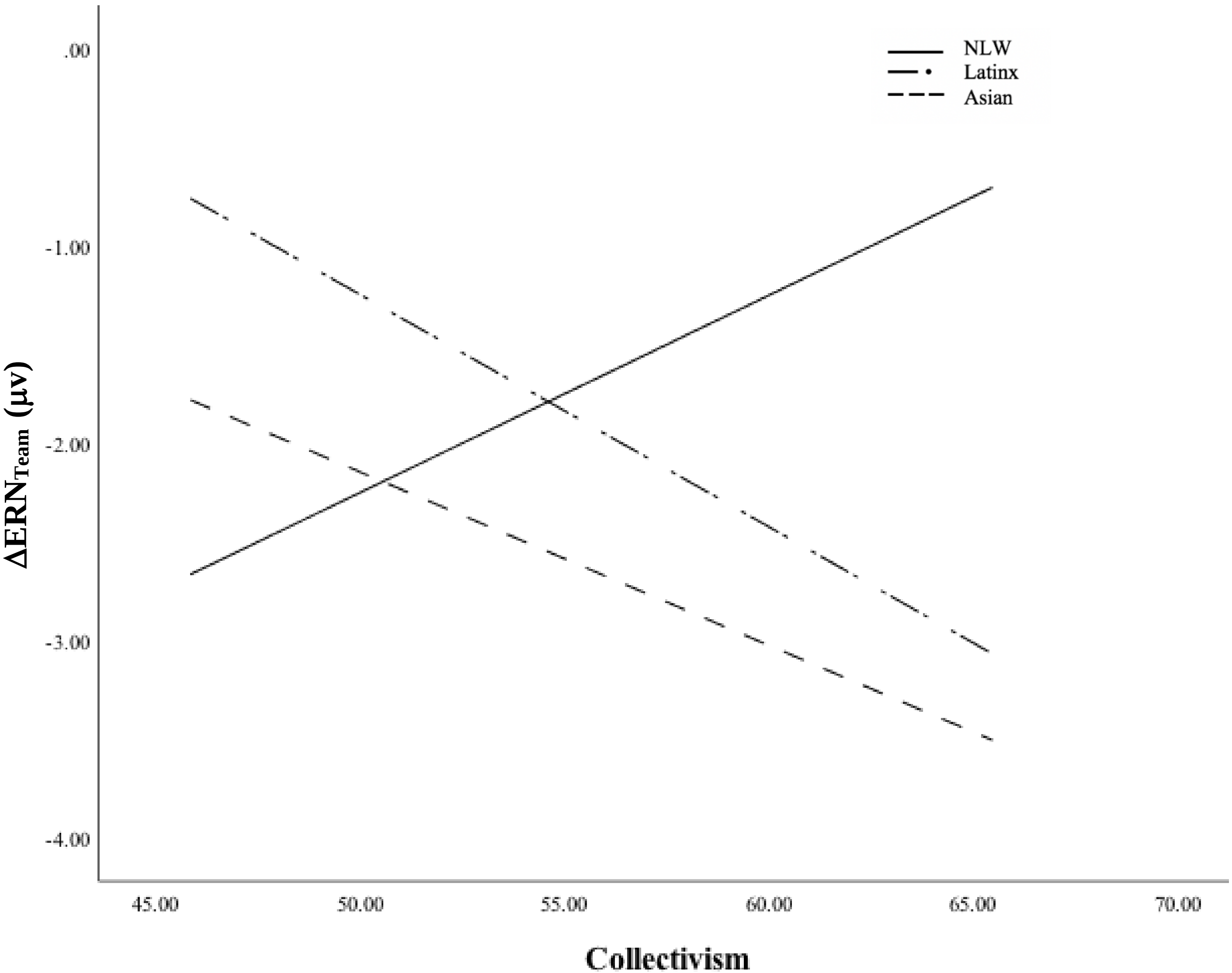

Figure 5. Association of collectivism and ΔERN_{Team} for NLW, Latinx, and Asian adolescents.

The second regression model confirmed that as hypothesized, collectivism did not show an association with $\Delta ERN_{Individual}$ (Hypothesis 2b). In the final regression model, a moderating effect of racial/ethnic group on the association of collectivism and $\Delta ERN_{Individual}$ - ΔERN_{Team} was detected (Hypothesis 2c, Hypothesis 2d), $F(2,83)=4.56$, $p=.01$. Although the overall model containing the interaction was not clearly significant ($p=.09$), the interaction was probed further because the moderating effect was hypothesized *a priori*. Conditional effects depicted in Figure 6 show that for NLW adolescents, greater collectivism is associated with less differentiation between ERN in the team and ERN in the individual condition whereas for Latinx adolescents, collectivism is associated with more differentiation NLW: $\beta=.06$, $p=.02$, Latinx: $\beta=-.07$, $p=.05$.

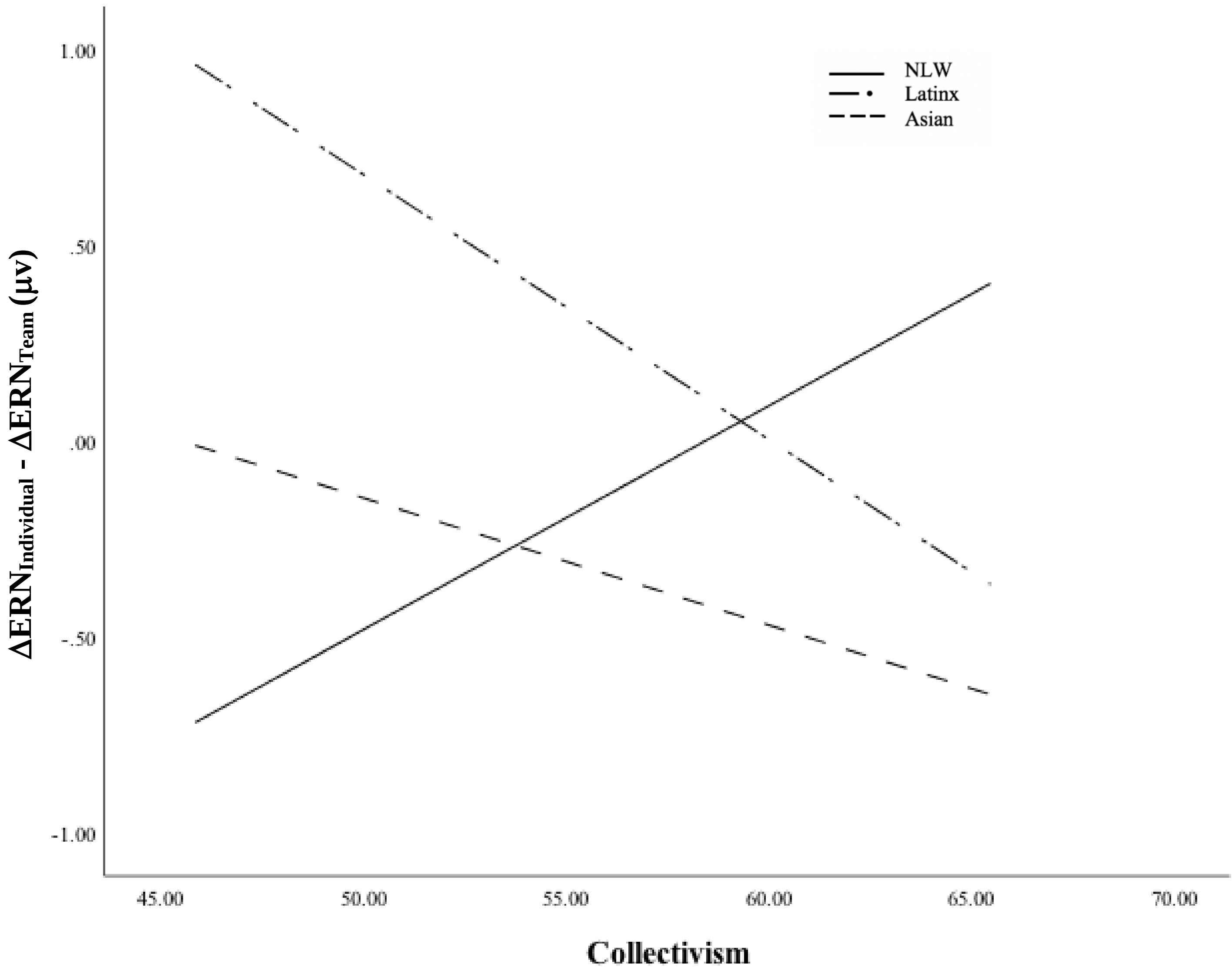

Figure 6. Association of collectivism and $\Delta ERN_{Individual}$ - ΔERN_{Team} for NLW, Latinx, and Asian adolescents.

Did the Social Feedback Task Designed to Elicit the FRN Work as Expected?

Confirming the presence of the FRN as elicited by the adapted Island Getaway task. As seen in Figure 7, there was an enhanced negativity following receipt of feedback at frontocentral sites. A repeated measures ANOVA involving electrode site (FCz, Cz, Pz) and feedback type (acceptance, rejection) was used to confirm the presence of a FRN and to determine at which electrode site the component was maximal. Mauchly's Test indicated a violation of the assumption of sphericity, therefore degrees of freedom were reported using Greenhouse-Geisser estimates. Main effects of site and response confirmed a negativity following receipt of feedback at frontocentral electrode sites that was more negative on rejection relative to acceptance trials, $F(1.44,141.84)=7.04$, $p=.004$, $\eta_p^2=.067$, $F(1,98)=8.12$, $p=.005$, $\eta_p^2=.077$, respectively. Post-hoc tests determined that FRN to acceptance and rejection was more negative at FCz than at Cz, acceptance: $t(98)=-5.94$, $p<.0001$, $d=.58$, rejection: $t(98)=-4.17$, $p<.0001$, $d=.57$. Results indicated that the social feedback task was successful in eliciting a FRN that varied as a function of feedback type.

One participant opted to not complete the FRN task. Two participants were excluded from analyses as these cases appeared to be a statistical outliers based on inspection of several indices (e.g., standardized residuals, Cook's Distance, leverage). Following these exclusions, the total sample size of participants included in analyses was 99.

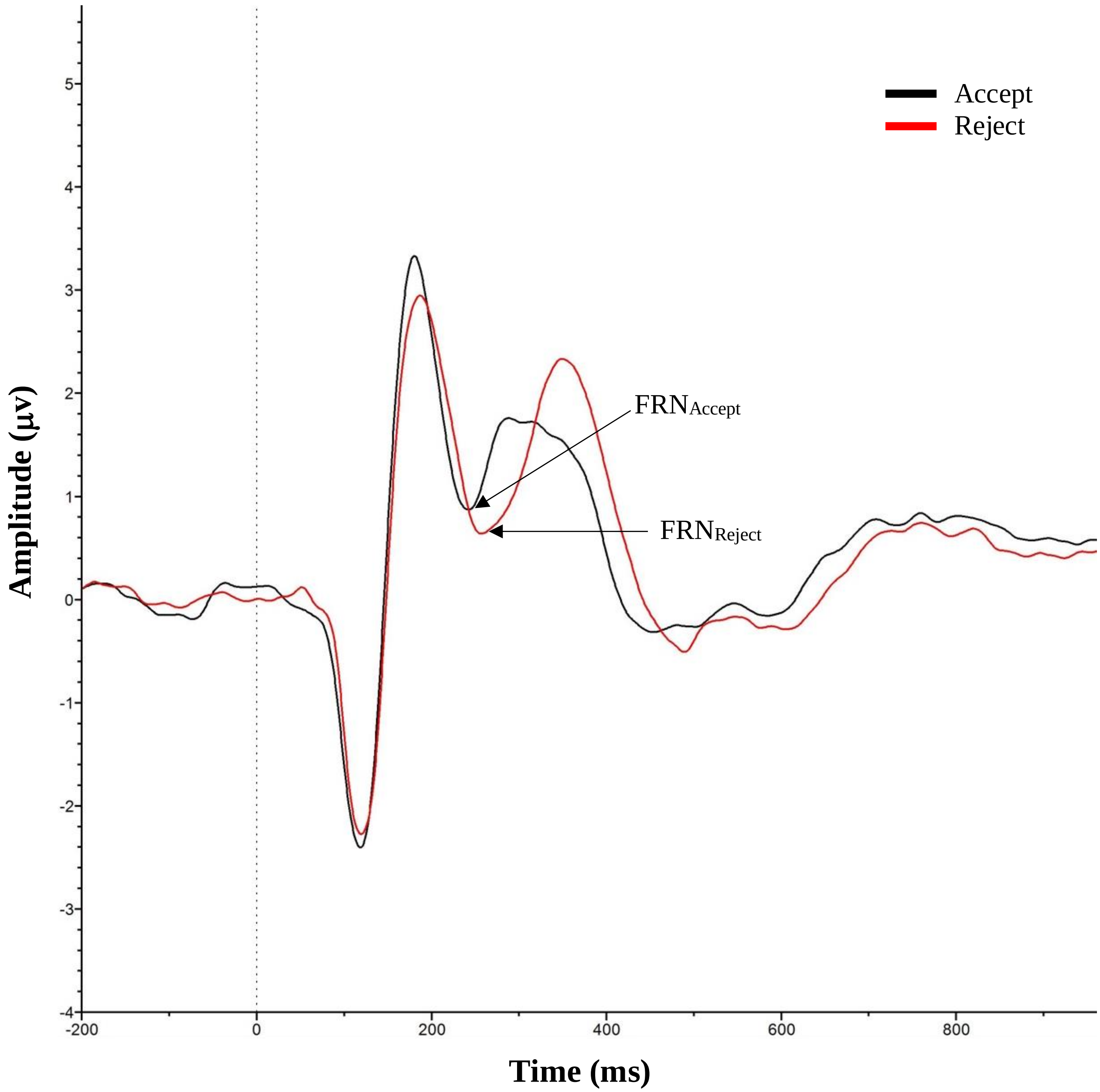

Figure 7. Neural response to acceptance and rejection feedback at FCz recording site, relative to onset of feedback stimuli (0 ms).

Mean amplitude measures of ERP components are summarized in Table 6. One-way ANOVAs revealed group differences by race/ethnicity for neural response to both acceptance and rejection feedback, $F(2,96)=5.45$, $p=.006$, $F(2,96)=4.57$, $p=.01$, respectively. Latinx adolescents demonstrated a more negative FRN to acceptance and rejection feedback than did Asian adolescents, acceptance: $t(58)=3.24$, $p=.002$, $d=.81$, rejection: $t(58)=2.76$, $p=.008$, $d=.74$. NLW adolescents demonstrated a more negative FRN to acceptance feedback than did Asian adolescents but comparable magnitude of neural response to rejection feedback, $t(56)=-2.26$, $p=.03$, $d=.53$.

Additionally, adolescents with clinically-elevated social anxiety demonstrated a more negative value for $\Delta FRN_{Accept\text{-}Reject}$, suggesting that clinically socially anxious adolescents differentiate more between acceptance and rejection feedback, $F(1,97)=7.12$, $p=.009$.

Table 6

Mean Amplitude and Difference Score Values in Microvolts (μv) of ERP Components Elicited by Peer Feedback Task at FCz

Condition	Component	Full Sample	NLW	Latinx	Asian
		M(SD)	*M(SD)*	*M(SD)*	*M(SD)*
		N = 99	*n = 39*	*n = 41*	*n = 19*
Acceptance	FRN	1.29(2.88)	1.31(2.70)$^{+}$	.65(2.48)*	3.17(3.39)$^{*+}$
Rejection	FRN	1.19(2.57)	1.41(2.22)	.41(2.58)*	2.43(2.77)*
	ΔFRN	.20(2.02)	-.10(2.10)	.25(1.80)	.74(2.27)

Note: M=Mean; SD= Standard deviation; NLW= non-Latinx White; FRN= Feedback-related negativity; *=groups significantly different, $p<.01$; +=groups significantly different, $p<.05$

Collectivism and Neural Response to Social Feedback

In line with Aim 3 of this study to identify cultural influences on neural response to social feedback, three parallel regression models were tested with FRN_{Accept}, FRN_{Reject}, and $\Delta FRN_{Accept\text{-}Reject}$ as outcomes. These regression models were designed to test the hypotheses that collectivism would be associated with enhanced FRN following rejection feedback (Hypothesis 3a), as well as a larger difference score from FRN following acceptance feedback (Hypothesis 3b), and that race/ethnicity would moderate these associations such that this effect would be more pronounced for Latinx and Asian adolescents (Hypothesis 3c). These hypotheses were not supported by results.

Social Anxiety and Neural Response to Error in a Social Context

Social anxiety and ERN following face priming in the flanker task. In line with Aim 4 of this study to characterize variation in neural response to error in a social context as a function of social anxiety, two regression models were run with ΔERN_{Angry} and $\Delta ERN_{Control}$ - ΔERN_{Angry} as outcomes. Regression models were set up to test the hypothesis that greater social anxiety would be associated with enhanced ERN in the angry face primed condition and more differentiation between ERN in the angry face primed condition and ERN in the control condition (Hypothesis 4a). Further, analyses tested the hypotheses that race/ethnicity and collectivism would moderate these associations such that there would be a more pronounced effect among Latinx and Asian adolescents (Hypothesis 4d) and those adolescents who endorse a higher degree of collectivism (Hypothesis 4e). Age was included as a covariate.

In the model with ΔERN_{Angry} as the outcome, race/ethnicity did not show a moderating effect and thus, the variable and its interaction with social anxiety were dropped from the model. The reduced overall model accounted for 28.18% of the variance in ΔERN_{Angry}, $F(4,51)=5.00$,

p=.002. Collectivism interacted with social anxiety in predicting ΔERN_{Angry}, $F(1,51)=12.73$, p=.0008. Probing of this interaction as illustrated in Figure 8 revealed conditional effects such that ΔERN_{Angry} was more negative as social anxiety increased for individuals who endorsed collectivism at one standard deviation above the mean score, β=-.09, p=.0009.

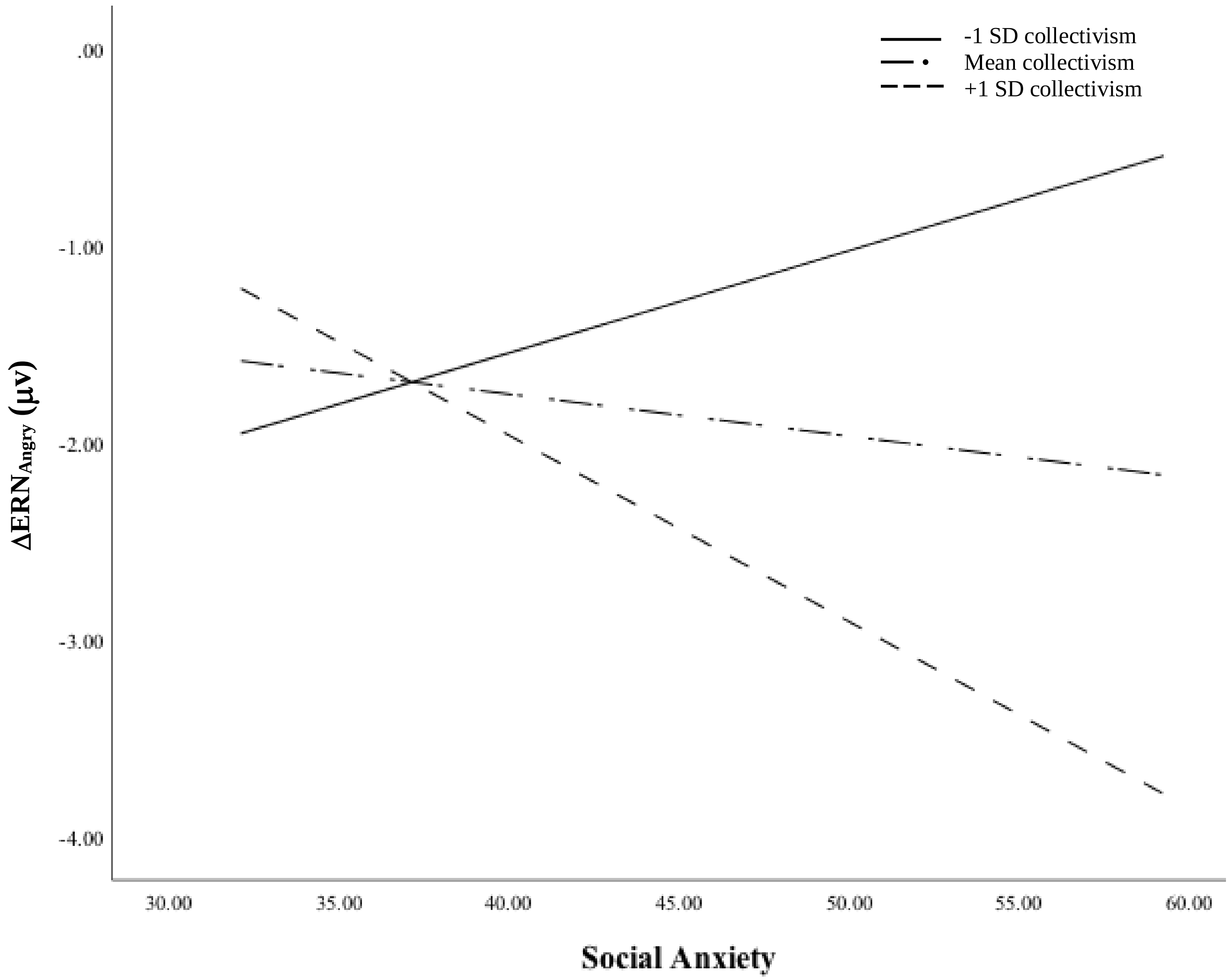

Figure 8. Association of social anxiety with ΔERN_{Angry} at -1 standard deviation, mean, and +1 standard deviation collectivism scores.

Social anxiety and ERN in the team condition as elicited by the go/no-go task. To test the hypothesis that greater social anxiety would be associated with enhanced ΔERN_{Team}, as well as greater differentiation between $\Delta ERN_{Individual}$ and ΔERN_{Team}, two regression models were conducted (Hypothesis 4b). In each model, social anxiety was included as the predictor and race/ethnicity and collectivism were included as moderators (Hypothesis 4d, Hypothesis 4e). Age was included as a covariate. For all outcomes, no main effects of social anxiety or moderating effects of collectivism or race/ethnicity were detected.

Social Anxiety and Neural Response to Social Feedback

Three regression models were conducted to test the hypotheses that greater social anxiety would be associated with enhanced FRN following peer rejection (Hypothesis 4c) and that this effect would be more pronounced for Latinx and Asian adolescents (Hypothesis 4d) and among those who endorse higher collectivism (Hypothesis 4e). In all regression models, age was included as a covariate.

In the first regression model where FRN_{Accept} was the outcome, collectivism did not demonstrate a moderating effect and thus, the variable and its interaction with social anxiety were dropped from the model. The overall reduced model accounted for 25.52% of the variance in FRN_{Accept}, $F(6,92)=5.25$, $p=.0001$. Race/ethnicity interacted with social anxiety in predicting FRN_{Accept}, $F(2,92)=4.41$, $p=.01$. Probing of this interaction revealed conditional effects represented in Figure 9 such that for NLW and Asian adolescents, FRN to acceptance feedback was more negative as social anxiety increased, NLW: $\beta=-.08$, $p=.03$, Asian: $\beta=-.14$, $p=.006$. This finding was unexpected, as neural response to peer acceptance was not predicted to be related to social anxiety.

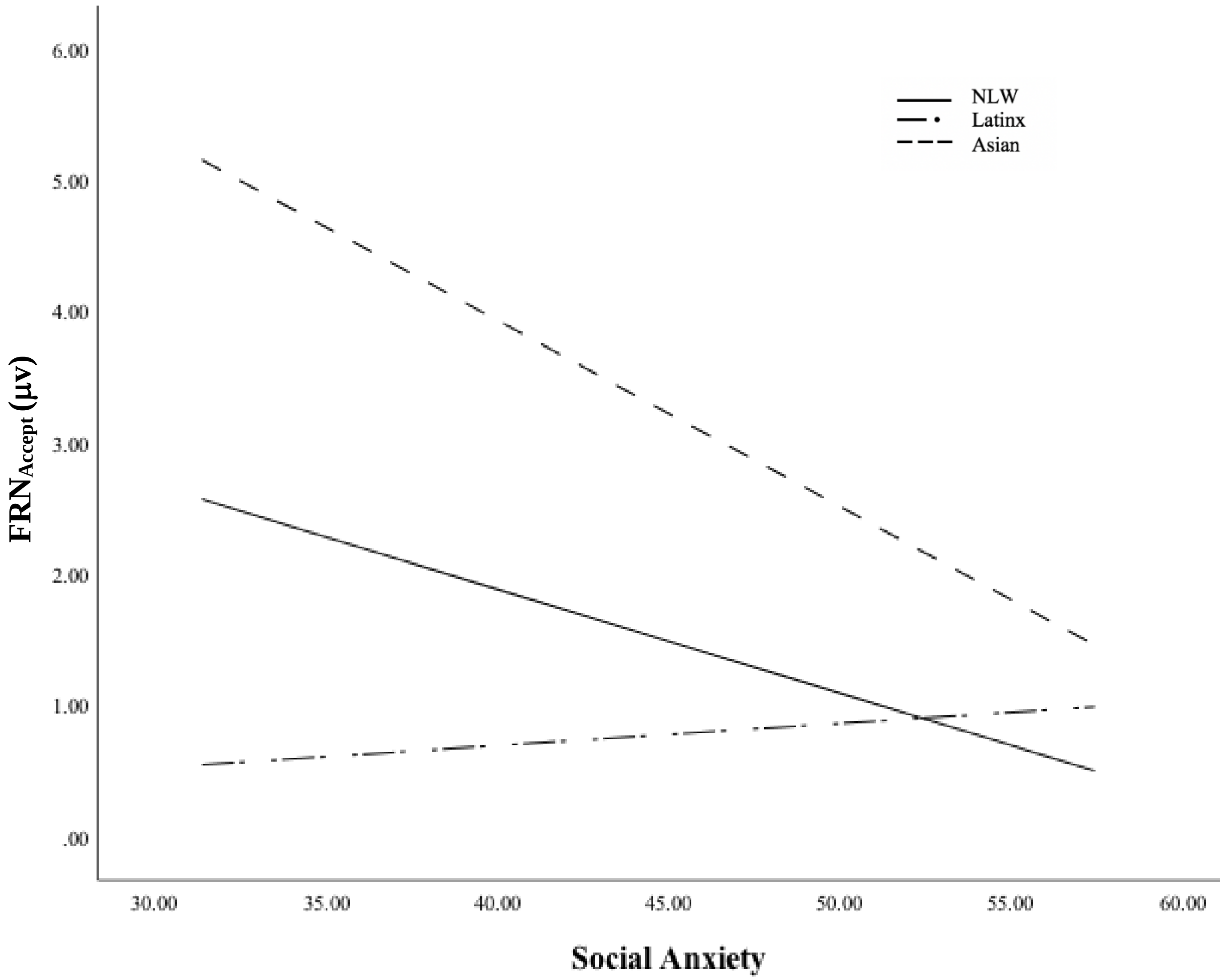

Figure 9. Association of social anxiety with $\mathrm{FRN}_{\mathrm{Accept}}$ for NLW, Latinx, and Asian adolescents.

In the second regression model where FRN_{Reject} was the outcome, collectivism did not demonstrate a moderating effect and thus, the variable and its interaction with social anxiety were dropped from the model. The overall reduced model accounted for 18.12% of the variance in FRN_{Reject}, $F(6,92)=3.32$, $p=.005$. Social anxiety and race/ethnicity interacted to predict FRN_{Reject}, $F(2,92)=4.16$, $p=.01$. Probing of this interaction revealed conditional effects illustrated in Figure 10 such that for Asian adolescents, FRN to rejection feedback was more negative as social anxiety increased, $\beta=-.14$, $p=.004$. These findings provided partial support for hypotheses that social anxiety would be related to neural response to peer rejection and that peer rejection would be more salient for Asian adolescents.

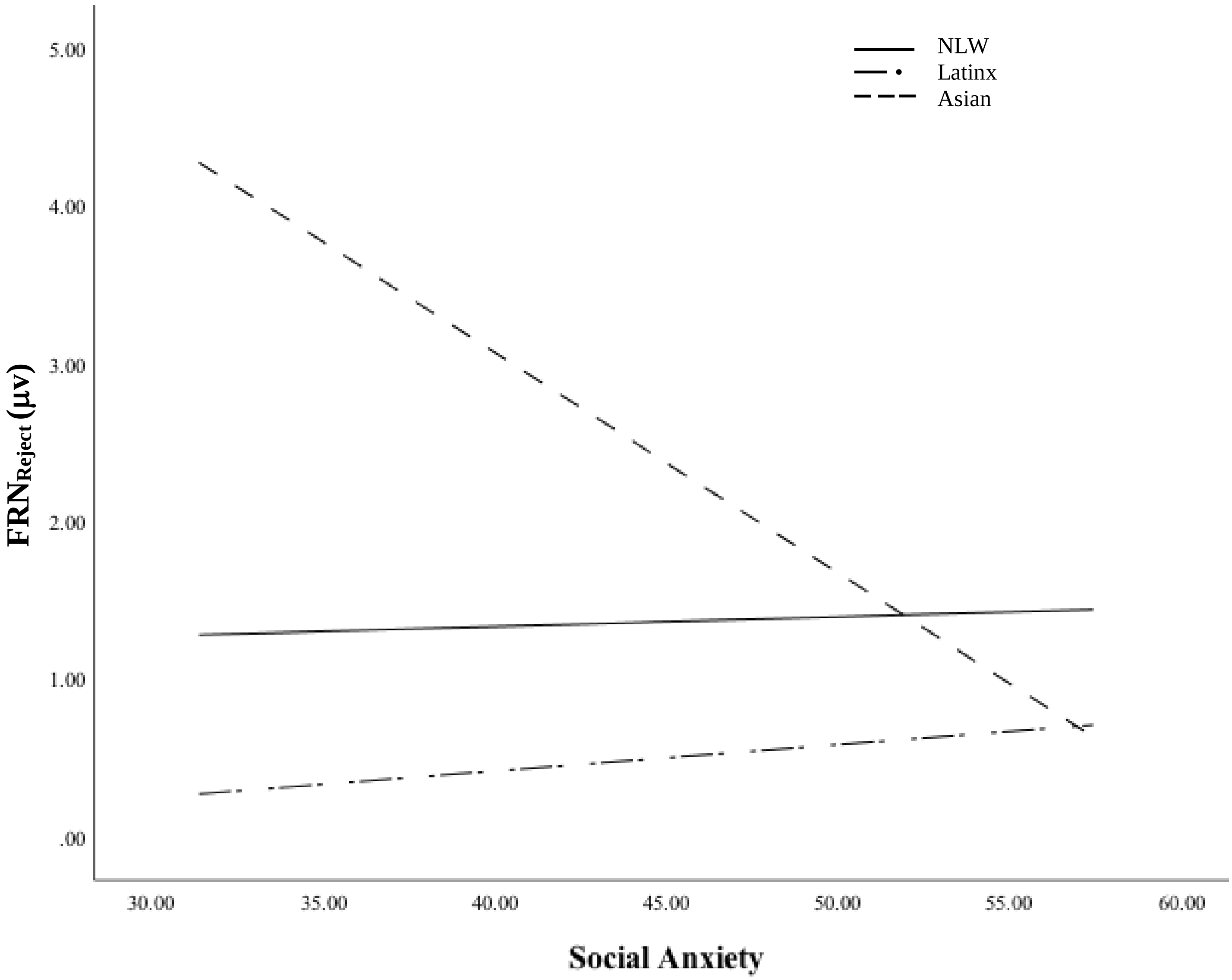

Figure 10. Association of social anxiety with FRN_{Reject} for NLW, Latinx, and Asian adolescents.

In the final regression model where $\Delta FRN_{Accept\text{-}Reject}$ was the outcome, collectivism did not demonstrate a moderating effect and thus, the variable and its interaction with social anxiety were dropped from the model. The overall reduced model accounted for 14.36% of the variance in $\Delta FRN_{Accept\text{-}Reject}$, $F(6,92)=2.57$, $p=.02$. Race/ethnicity interacted with social anxiety in predicting the outcome, $F(2,92)=3.21$, $p=.04$. Probing of this interaction revealed conditional effects illustrated in Figure 11 such that for NLW adolescents there was greater differentiation between acceptance and rejection feedback as social anxiety increased, $\beta=-.08$, $p=.002$. Findings provided partial support for the hypothesis that greater differentiation between acceptance and rejection feedback would be observed as social anxiety increased.

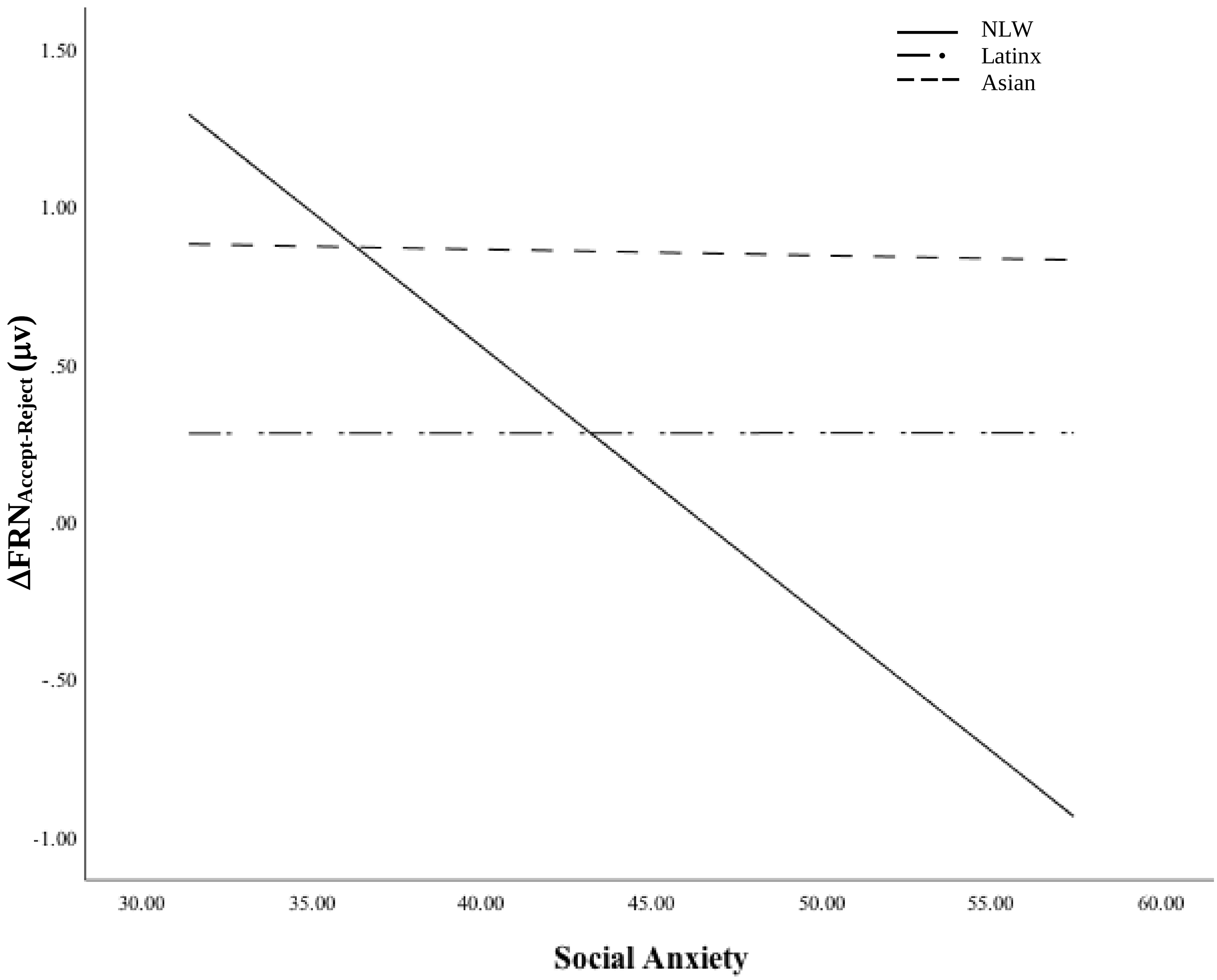

Figure 11. Association of social anxiety with $\Delta FRN_{Accept\text{-}Reject}$ for NLW, Latinx, and Asian adolescents.

Discussion

The present study applied a RDoC framework to the examination of factors thought to contribute to cultural and developmental disparities in social anxiety symptomatology. A strength of the RDoC initiative is that it strives to move away from a basic "nature versus nurture" viewpoint of psychopathology by considering psychological and biological phenomena as equally weighted and integrated constructs (Kozak & Cuthbert, 2016). In line with this premise, the present research attempts to combat the common misconception that RDoC is incompatible with culture (Lake, Yee, & Miller, 2017) by examining the interplay of individual differences in self-construal (i.e., collectivism) with psychophysiological measures of self-regulatory processes (i.e., error-monitoring (ERN) and feedback response (FRN)). The study also examined ERN and FRN in relation to a dimensional measure of social anxiety among diverse adolescents in order to begin to identify pathways by which vulnerability for psychopathology may be increased. Although the project is limited in several ways, as described in detail within this section, it also improves upon extant research aimed at examining cultural variation in psychophysiological outcomes. Namely, in line with the spirit of RDoC, collectivism was measured continuously whereas in previous research, cultural views have been inferred based on racial/ethnic group membership, and/or racial/ethnic group was used as the primary predictor of interest (e.g., Cai, Wu, Shi, Gu, & Sedikides, 2016; Hot, Saito, Mandai, Kobayashi, & Sequiera, 2006; Jiang, Varnum, Hou, & Han, 2014; Kitayama & Murata, 2013; Lahat, Todd, Mahy, Lau, & Zelazo, 2010; Liu, Rigoulot, & Pell, 2015; Liu, Rigoulot, & Pell, 2017; Masuda, Russell, Chen, Hioki, & Caplan, 2014; Murata, Moser, & Kitayama, 2013; Sui, Liu, & Han, 2009; Sui, Hong, Liu, Humphreys, & Han, 2013; Varnum & Hampton, 2017; Wang, Umla-Runge, Hofmann, Ferdinand, & Chan, 2014; Wang, Deng, Sui, & Tang, 2014; Zhu et al., 2016; Zhu, et al., 2016).

Although race/ethnicity was examined as a moderator in the present study, the goal of doing so was not to demonstrate that there are hard-wired differences between groups. Rather, race/ethnicity stood as a proxy for the individual and structural factors that were not readily measured in the present study and was used to help highlight variability in how the brain responds to the sociocultural environment (Han et al., 2013). Further, the present research extends the literature on neural correlates of social sensitivity during adolescence (for review, Somerville, 2013), an area of study that has been identified as an important future direction for the field of developmental neuroscience (Fuligni, Dapretto, & Galván, 2018). Additionally, the present research contributes to the growing literature implicating abnormalities in reward processing in developmental models of social anxiety risk (Caouette & Guyer, 2014).

Overall, some but not all study hypotheses were supported. Aim 1 of this study to replicate the facial priming effect on the ERN was not achieved; collectivism was not found to be associated with enhanced ERN in face primed conditions. However, when the manipulation of social context was shifted from a facial cue to a developmentally-appropriate team condition, as specified in Aim 2, an association between collectivism and enhanced ERN in a social context emerged, which was most robust for Latinx adolescents. Although Aim 3 of this study which focused on identifying an association between collectivism and neural response to socially-salient feedback was not supported, analyses relating ERP components with social anxiety, in line with Aim 4, demonstrated that FRN following social feedback was strongly linked with a dimensional measure of social anxiety. The relationships of ERN and FRN to social anxiety were qualified by moderating effects of collectivism and race/ethnicity, respectively. Implications of these findings are expanded upon below.

Latinx and Asian Adolescents Endorse More Collectivism than NLW Adolescents

Results from primary analyses can be best understood in the context of several notable sample characteristics that emerged. Although the sample in the present study was more diverse than is seen routinely in psychophysiological research, there were some potential confounds in regards to group differences by demographic variables. Racial/ethnic group differences in self-reported collectivism were as anticipated based on cross-cultural research in adults, with Latinx and Asian adolescents endorsing more collectivism than NLW adolescents. This finding is intriguing, though, when considered alongside research examining developmental trends in self-construal ratings among U.S. youth. A generational pattern of increasing individualism and related traits (e.g., assertiveness, extraversion) has been observed among teenagers in the U.S. (Twenge, 2001; Twenge & Campbell, 2008). However, adolescents in the present sample did not uniformly endorse self-construal ratings in line with this trend. Variability in self-construal is likely a result of intersecting identities, and this finding supports the notion that the factors that influence the development of self-construal among adolescents occur at multiple levels. Societal influences are certainly impactful (Park, Twenge, & Greenfield, 2014). However, more proximal family-level factors like socialization and parenting practices are also meaningful vehicles of cultural transmission (Roest, Dubas, & Gerris, 2009; Friedlmeier & Friedlmeier, 2012). The process of how adolescents adopt collectivistic and individualistic values has been specifically examined. Research suggest that positive perceptions of parental practices predict the degree to which an adolescent will assume collectivistic or individualistic views; in one study, perceived quality of family relationships only mediated the association for acquisition of collectivistic views (Prioste, Narciso, Goncalves, & Pereira, 2015). When attempting to understand the mechanisms by which an adolescent's endorsement of collectivism influences psychopathology outcomes, it is important to keep in mind the factors that contribute to how these cultural values arise. For example, examining concordance between parent and child ratings of collectivism, together with perceptions of family environment, may provide more insight into the prognostic utility of an adolescent's ratings of collectivism in clarifying psychopathology risk.

Although Latinx and Asian adolescents endorsed more collectivism than NLW adolescents, Asian adolescents endorsed more individualism than both Latinx and NLW adolescents. While individualism was not a focus of this study, the implications of the interaction between collectivism and individualism on neural and psychopathology outcomes is explored in analyses included in the Appendix.

Latinx and Low-income Adolescents Endorse the Least Amount of Social Anxiety Relative to Counterparts

An unanticipated finding was that Latinx adolescents endorsed less social anxiety than NLW adolescents. Similarly unexpected, adolescents from families characterized as low-income endorsed less social anxiety than non-low-income counterparts. Based on published benchmarks (Cohen, 1988), the strength of association between race/ethnicity and low-income status in the present sample indicated a large effect. As such, it is difficult to disentangle these two variables, especially when attempting to understand why Latinx adolescents endorsed less social anxiety, a finding counter to other reports (McLaughlin, Hilt, & Nolen-Hoeksema, 2007; Polo & Lopez, 2009). The literature regarding the association between SES and anxiety symptoms is more mixed. In the adult literature, it is well-documented that individuals in low-SES households experience more daily strain and increased overall stress (Lorant et al., 2003; Wadsworth et al., 2008), which has been linked with greater risk for anxiety (Grover, Ginsburg, & Ialongo, 2005). Among youth, this association is not as well characterized and the limited studies that have examined this topic have produced contrary results. While some studies have found a clear link between low-SES and greater risk for anxiety (Miech, Caspi, Moffitt, Entner Wright, & Silva, 1999), others have found only certain facets of SES to be pertinent (e.g., maternal educational attainment) (Ozer et al., 2008) or an opposite effect such that low-SES youth endorse less anxiety than high-SES counterparts (Merikangas et al., 2010). In the present study, this reduced level of psychopathology among Latinx and low-income adolescents could be attributable to several factors. First, it is certainly possible that adolescents are underreporting symptoms or do not view symptoms of social anxiety to be distressing. It may be the case that social anxiety symptoms are present to the same or a greater degree relative to other racial/ethnic groups but these symptoms are not being communicated or interpreted as pathological. Alternatively, symptoms could be present to a lesser degree due to a third variable that mitigates risk. For example, family-level strengths can be protective for youth even when experiencing environmental stressors such as poverty (Hammack, Richards, Luo, Edlynn, & Roy, 2004). In line with this view, it is known that youth exposed to poverty have been shown to exhibit significant resilience (McBride Murray, Berkel, Gaylord-Harden, Copeland-Linder, & Nation, 2011), and integrative models posit that economic strain can promote adaptive behaviors and competencies (Garcia Coll et al., 1996). Still, there is some evidence that low- and middle-income youth are more likely to rely on disengagement coping strategies like denial and avoidance rather than engagement strategies like problem solving (Neuendorf, Kim, & Evans, 2009). Although disengagement strategies are generally considered to be less adaptive, they do not necessarily manifest in worse outcomes. For example, in a sample of African American and Latinx adolescents experiencing poverty, youth who predominately utilized problem solving coping strategies and youth who relied on the avoidance coping strategy of substance use both had fewer internalizing symptoms (Tolan, Gorman-Smith, Henry, Chung, & Hunt, 2002). As such, it would be important to understand what variables are accounting for this lower level of psychopathology among Latinx and low-income youth, as understanding if these factors are adaptive (e.g., family support) or maladaptive (e.g., avoidant coping) could guide future efforts to bolster or modify these variables when developing interventions.

Finally, it was assumed that higher collectivism scores would be associated with more social anxiety based on research that has predominately included samples from East Asian countries and/or Asian Americans (Heinrichs et al., 2006; Schreier et al., 2010). It is thought that collectivism engenders greater social anxiety because certain behaviors that are consistent with the norms and goals of collectivism are reinforced (Mesquita & Walker, 2003). Socialization practices are oriented toward goals such as group harmony and cooperation, which may manifest in behaviors that are linked with internalizing disorders (e.g., reticence, shyness, fearfulness) (DiBartolo & Rendon, 2012; Heinrichs et al., 2006; Yoon & Lau, 2008). However, a negative correlation between these two variables was observed in the present sample. This is contrary to evidence in Asian and Asian American samples which suggests a positive association between collectivism and social anxiety that is particularly pronounced for those residing in the U.S., a predominately individualistic society (Caldwell-Harris & Aycicegi, 2006). However, the negative association observed is not entirely discrepant with the small body of literature that has examined the association of collectivism and internalizing symptoms among Latinx youth. In the two extant studies that have addressed this link among Latinx children, there was only a small positive correlation detected between collectivism and anxiety (Varela et al., 2004) as well as a non-significant association (Varela et al., 2009). That being said, the inclusion of a more diverse sample does not seem to fully explain these relationships. When examined separately within racial/ethnic groups, collectivism and social anxiety demonstrated a negative association of comparable magnitude in each group. Together, this suggests that an adolescent's ratings of collectivism appear to show a protective effect that is not unique to a certain racial/ethnic group. As such, it is possible that collectivism ratings may actually represent a broader construct that reflects the factors that contribute to the transmission of cultural values. Using the model proposed by Prioste, Narciso, Goncalves, and Pereira (2015) in which perceived family support mediates the association of parenting practices and adolescents' acquisition of collectivistic views, it is possible that higher adolescent collectivism ratings might map onto more positive perceptions of family relationships, which could account for the negative association observed in the present study.

Face Priming and Team Condition: Did Manipulations of Social Context Modulate ERN?

Collectivism was not associated with greater neural response to error in the angry face primed condition or the difference between ERN in the angry face primed condition relative to the control condition, contrary to hypotheses based on results from Park and Kitayama (2014). There exist both methodological and conceptual explanations for this lack of significant results.

A first explanation could be that unanticipated methodological confounds were introduced when adapting the task. A possible indication that the task was not appropriate for the present study was the number of participants excluded due to insufficient error trials. Approximately 45% of participants were not included in analyses for this reason. Although participants excluded from analyses did not differ from those included in analyses on the basis of demographic variables, it is possible that these adolescents vary in some other manner that impacted the motivational salience of errors. For example, a variable not measured in the present study that could be relevant to understanding the better than expected accuracy of participants is video game use. In behavioral data aggregated from nine different speeded response tasks completed by youth and adult participants across seven studies, experienced video game players were found to be consistently faster in responding than novice video game players (Cohen's *d* effect sizes ranging from 0.48 to 1.47 depending on task) (Dye, Green, & Bavelier, 2009). Generally, there is an understanding that greater speed in responding results in less accuracy. As such, it is possible that the adolescents retained in analyses were those with more video game experience, increasing the likelihood that youth were motivated simply by the game-like nature of the flanker task. This, coupled with reduced power to detect effects, may have accounted for the lack of association between collectivism and ERN.

Further, it is important to note that the threshold for excluding a participant due to insufficient error trials was derived from previous research. However, reliability is not a fundamental property of a measure (Vacha-Haase, 1998; Vache-Haase et al., 1999) and should be determined in a manner that is context specific. That is, the characteristics of a sample (e.g., clinical versus community, adult versus pediatric) influence how a measure manifests and the meaning of this measure (Clayson & Miller, 2017). In the present study, it would have been more rigorous to exclude cases based on sample-specific reliability, as cases that were appropriately reliable may have been excluded arbitrarily and vice versa. Given that the effect size of an association can be attenuated by low reliability (Baugh, 2002; Clayson & Miller, 2017), it is possible that a relationship between collectivism and ERN was obscured for this reason. Assessing reliability of the ERN would be an especially important next step given the unique composition of the sample, and doing so would constitute a contribution to the field. Although the reliability of the ERN has been examined extensively as a function of clinical status, development, and task type (e.g., Baldwin et al., 2015; Foti et al., 2013; Meyer, Bress, &

Proudfit, 2014; Meyer, Riesel, & Proudfit, 2013; Pontifex et al., 2010), there is virtually no research on psychometric properties of the ERN among diverse youth.

Although findings should be considered in light of these methodological considerations, cultural factors may also account for the lack of association between collectivism and ERN. In the study from which the task was adapted, the authors surmised that Asian undergraduates would demonstrate greater sensitivity to social-evaluative threat (Kim & Markman, 2006) and that a race-neutral computer generated facial image would be sufficient to evoke this sense of threat. As described previously, although the task specifications and the control image from the Park and Kitayama (2014) study were preserved, the stimuli intended to evoke social-evaluative threat in the present study were changed. Specifically, photographic images of adolescents of varying affect (i.e., happy, neutral, and angry expressions) taken from a standardized facial stimuli set (Egger et al., 2011) were included as priming stimuli in lieu of the schematic neutral face image. In part this was motivated by concern that the flanker task as originally developed by Park and Kitayama (2014) might not elicit the same neural research in adolescents as seen in an adult sample, given research that shows a puberty-related decline in sensitivity to neural faces, suggesting a developmental shift in the function/meaning of neutral facial cues (Ferri, Bress, Eaton, & Proudfit, 2014). Although attempts were made to select the most diverse appearing range of images possible, when the stimuli set was developed, the authors did not collect racial/ethnic information from the youth who were photographed (Egger et al., 2011). Thus, there was no ability to ensure empirically that a balance of stimuli from different racial/ethnic groups was achieved. The association between collectivism and ERN, as well as racial/ethnic group differences in ERP measures, may have been obfuscated by neural reactivity to in-group/out-group images, a phenomenon that is well-documented in the fMRI literature (Shkurko, 2013). Several elements of task design including the gender and perceived race/ethnicity of social stimuli, or even the wording of instructions, could have activated stereotype-threat processes. Examination of stimulus-locked components could be useful in disentangling these effects, particularly the N170 which has been shown to be sensitive to the perceived salience of affective stimuli (Montalan et al., 2008; Zhang et al., 2014).

Although successfully used with undergraduate samples, it is also possible that facial stimuli are not sufficient to elicit social context among adolescents. There are developmental differences in motivational systems between adults and youth, which are posited to manifest in the ERN. In children and adolescents, social variables such as observation and evaluation have been found to enhance ERN (Buzzell et al., 2017; Kim, Iwaki, Uno, & Fujita, 2005) while nonsocial variables (e.g., monetary rewards) do not (Maruo, Sommer, & Masaki, 2017; Torpey, Hajcak, & Klein, 2009). Although facial stimuli could indeed be considered a social cue, these images may not have represented a motivationally significant context for adolescents.

Comparatively, the social context manipulation included in the go/no-go task did appear to be successful in tapping sensitivity to social factors. In this task, adolescents were told that in some blocks they were earning points to help a peer who had previously participated in the study earn points toward a shared prize, and in other blocks, they were earning points for only themselves. As anticipated, collectivism was differentially associated with ERN as a function of condition (i.e., team versus individual), in line with findings suggestive that ERN is sensitive to contextual factors. This finding strengthens the relatively small body of research demonstrating that manipulations of social context involving peer affiliation (e.g., observation/evaluation by a peer) can result in enhanced ERN among adolescents (Barker, Troller-Renfree, Bowman, Pine, & Fox, 2018; Buzzell et al., 2017). In line with evidence that the ERN is reflective of the interaction of individual differences and contextual factors (Riesel et al., 2012; Weinberg et al., 2016), the present research also extends biopsychosocial models of social motivation (Blascovich, Mendes, Hunter, & Salaoman, 1999; Blascovich & Tomaka, 1996). Specifically, the present findings demonstrate that an individual's cultural views can influence the perceived value of the social context and correspondingly, the motivational salience of errors occurring in a social context.

Neural Response to Social Feedback Does Not Vary as a Function of Collectivism

Contrary to hypotheses, collectivism did not demonstrate an association with FRN following acceptance and rejection feedback in the adapted Island Getaway task. Previous research that established a link between collectivism and FRN extended the work of Park and Kitayama (2014) by using a face prime to elicit social-evaluative threat in the context of a gambling task (Hitokoto, Glazer, & Kitayama, 2016). In work by Hitokoto and colleagues (2016), the conclusion that collectivism was associated with neural response to social feedback was derived by examining the correlation of collectivism with the difference in FRN following monetary feedback trials primed by a face image and monetary feedback trials primed by a scrambled face image. Put differently, the authors found collectivism to be related to the difference between FRN in a social context relative to FRN in a non-social context. One reason why a similar effect was not detected in the present study could be that a comparator condition with non-social feedback (akin to the scrambled face prime) was not included. In the present study, it was initially hypothesized that the perceived salience of acceptance and rejection feedback would vary as a function of collectivism, such that adolescents who endorsed greater collectivism would demonstrate enhanced FRN following rejection feedback and greater differentiation between FRN following acceptance relative to rejection feedback. It is possible that by only including social feedback without non-social comparator trials contributed to the failure to replicate previous findings. Interestingly, while FRN showed no relationship to collectivism, it was more robustly related to social anxiety than ERN.

ERP Components are Related to Social Anxiety

An association between social anxiety and ERN following priming by an angry face was observed among adolescents who endorsed a high degree of collectivism (i.e., collectivism ratings one standard deviation above the mean). Facial emotion processing has been examined in social anxiety samples, given the relevance of interpersonal cues to the phenomenology of the disorder. Activation of the anterior cingulate cortex has been shown to be enhanced among patients with SAD when presented with stimuli depicting facial expressions of disgust, suggesting deficits in response inhibition to negative stimuli (Amir et al., 2005). Present results suggest that this effect is enhanced by collectivism, supporting collectivism as a variable that heightens sensitivity to negative and/or threatening social cues.

Although neural response to acceptance and rejection feedback did not appear to be associated with collectivism, robust relationships with social anxiety were revealed. A negative association between social anxiety and FRN_{Accept} was observed for NLW and Asian adolescents, as well as with FRN_{Reject} for Asian adolescents. Greater differentiation between acceptance and rejection feedback was associated with greater social anxiety only for NLW adolescents. These overall patterns of association are in line with previous studies that have identified enhanced neural response to acceptance feedback among individuals with SAD (Cao et al., 2015), as well as greater differentiation between acceptance and rejection feedback as social anxiety increases (Kessel, Kujawa, Proudfit, & Klein, 2015; Kujawa et al., 2014). However, the differential patterns of association by racial/ethnic group require further unpacking.

Findings related to the moderating effect of racial/ethnic group were in part unexpected. Particularly notable was that Latinx adolescents demonstrated greater neural response to social feedback overall, which we would anticipate would result in greater social anxiety. However, this subgroup was characterized by less social anxiety than other racial/ethnic groups and there was no association between FRN and social anxiety detected in this subgroup. Cultural factors may account for this pattern of findings. In cultural groups that are predominantly collectivistic, attunement to social feedback is viewed as critical for maintaining desirable behaviors that benefit the group (Heine, Takemoto, Moskalenko, Lasaleta, & Henrich, 2008; Henrich et al., 2001). Emotional sensitivity has been shown to promote adaptive and flexible social behavior (Rosen et al., 2017), which may be particularly advantageous during adolescence (Crone & Dahl, 2012; Pfeifer & Allen, 2012). For example, research shows that neural and behavioral sensitivity to reward in adolescence can lead to greater response inhibition, which behaviorally is associated with lower risk-seeking and susceptibility to peer pressure (Pfeifer et al., 2011; Telzer, Ichien, & Qu, 2015). In the present sample, it may be that Latinx adolescents are sensitive to social feedback but this neural response is not necessarily linked with a maladaptive outcome. A similar pattern has been found in fMRI research involving low-SES youth. For example, adolescents exposed to childhood stressors were shown to recruit a broader neural network than adolescents who had not experienced childhood stress when completing a cognitive flexibility task, despite both groups demonstrating comparable task performance (Mueller et al., 2010). These findings suggest that when there are differences in neural activation between groups that do not translate to behavioral differences, it is possible that adaptive compensation strategies have emerged that account for this outcome. Alternatively, there could be a protective factor at play for Latinx adolescents that buffered the association between heightened neural response to feedback and social anxiety. Parent attitudes and practices, family-related factors such as *familismo*, and religious values are candidates for further exploration. Preliminary correlations with these variables are presented in the Appendix.

In light of this evidence, it is perhaps counterintuitive that among Asian adolescents there was a link between heightened sensitivity to social feedback and psychopathology. Although Asian culture is generally characterized by a high degree of collectivism, as also seen in Latinx culture, it is possible that variability in how social cues are processed could explain why heightened neural response to feedback was associated with social anxiety for Asian but not Latinx adolescents. Some have hypothesized that among Asians and Asian Americans, socialization practices in line with collectivistic self-construal lead to a heightened attunement to the feelings and emotions of others (Hong & Woody, 2007; Okazaki, 1997). In part, this attunement develops in youth through the use of shame by parents (Fung, 1999). These practices are thought to result in a high degree of relational sensitivity and social awareness (Lieber, Fung, & Leung, 2006), but can also engender increased worries about competency in anticipating, recognizing, and evaluating the affective reactions of others. These types of worries are thought to be related to a cultural phenomenon salient to Asians called loss of face, which refers to a perceived sense of loss of social status as a result of an interpersonal misstep (Zane & Yeh, 2002). Loss of face concerns are more prevalent among Asian Americans than among European American counterparts (Zane & Yeh, 2002), and yet despite this cultural priority on attunement to social cues, Asian Americans have been shown to demonstrate a reduced ability to accurately recognize emotions in others (Beaupre & Hess, 2005; Elfenbein & Ambady, 2003; Lau et al., 2008). Both shame and loss of face concerns show a link with fear of negative evaluation and social avoidance and distress among Asian Americans (Leong et al., 2008), and loss of face concerns were found to mediate ethnic differences in social anxiety between Asian American and European American undergraduates (Lau et al., 2008). This body of work is in line with the present findings that as social anxiety increased, Asian adolescents showed heightened neural response to both acceptance and rejection feedback, but not enhanced differentiation between neural response to acceptance and rejection feedback.

Findings in the NLW subsample were consistent with previous research that has used the Island Getaway task. As found in previous research (Cao et al., 2015), social anxiety was associated with enhanced neural reactivity to acceptance feedback, but not to rejection feedback. In line with findings from Kujawa et al. (2014), there was also an association between social anxiety and greater differentiation between neural response to acceptance and rejection feedback. Given research that has shown social rejection to be interpreted as threatening (Cristofori et al., 2013; Harrewijn et al., 2018; van Noordt et al., 2015), it is somewhat surprising that social anxiety was associated with FRN following acceptance feedback but not following rejection. However, it is possible that this pattern of responding is attributable to biased expectancies regarding feedback seen among youth with social anxiety. Anxious youth have been shown to make negatively biased social predictions (e.g., appraising peers' social desirability to be higher than their own (Smith, Nelson, Rappaport, Pine, Leibenluft, & Jarcho, 2018)) that correspond with symptom severity (Caouette et al., 2014; Guyer et al., 2008; Haller et al., 2016). As such, it may be the case that socially anxious youth find acceptance feedback to be unexpected, which is reflected in enhanced FRN.

Alternatively, it is also possible that the more robust link between social anxiety and neural response to acceptance feedback relative to rejection feedback could indicate a deficit among adolescents with social anxiety in their ability to process negative social feedback. In other research that has identified this same pattern, the differential association was conceptualized as an attenuated response to rejection feedback, rather than an exaggerated response to acceptance feedback (Cao et al., 2015), akin to the blunted response to rejection feedback seen among individuals with depression (Foti & Hajcak, 2009). A lack of sensitivity to negative social information has been posited to account for the emergence and maintenance of social anxiety, as it could result in an impaired ability to favorably adjust behavior in response to negative feedback (Ruff & Fehr, 2014). Further, there is some evidence that youth with more internalizing symptoms are less reactive to rejection feedback. In one study, children with internalizing disorders reported feeling less sad when rejected by peers than non-anxious peers (Morales, Vallorani, & Pérez-Edgar, 2018), supporting the notion that the experience of rejection confirms expectations for anxious youth. That is, rejection is not perceived to be unexpected because it is part of an ongoing pattern of negative social interactions that lead to or are a consequence of internalizing problems (Parker et al., 2006).

Limitations

Several methodological and conceptual limitations of the project exist that should be considered when interpreting results. Some have already been highlighted, including the reduced sample size of the participants included in analyses of flanker task data, the lack of sample-specific reliability measures for ERP components, and the potential for the introduction of unintended confounds when adapting the flanker task. Additional limitations are addressed below.

Factors related to EEG data acquisition and processing could have introduced measurement error and diminished the ability to make conclusions about associations of ERP components with psychological constructs (Clayson & Miller, 2017). It should be noted that some steps were taken to minimize noise during EEG recording, including prompting participants throughout recording to avoid introducing irrelevant physiological activity (e.g., muscle tension in face). Regardless of attempts to minimize vulnerability to noise, there are likely unaccounted for sources of measurement error that would be important to assess and quantify as a next step.

Sample characteristics also present potential confounds. First, the tasks used in the present study have not been previously validated in a diverse sample, which limits the ability to determine to what extent methodological issues interfered with tests of conceptual associations. Further, racial/ethnic groups were not matched on demographic variables, resulting in a particularly notable imbalance between groups in terms of income distribution.

A major limitation of the present study's ability to assess developmental processes is that data were cross-sectional. As such, inferences are not able to be made regarding developmental trajectories, sensitive periods, or dynamic interaction of systems, three neurodevelopmental concepts that are well positioned for examination through a RDoC lens (Casey, Oliveri, & Insel, 2014). Longitudinal examination of cultural processes in tandem with neurodevelopment would be particularly useful in clarifying the time course of and mechanisms by which risk for psychopathology emerges. Cross-sectional data, as was collected in the present study, cannot be leveraged to achieve this.

Next, social feedback was presented in a passive manner, which may have impacted engagement. Although the paradigm did appear to elicit the FRN in a manner that was consistent with previous studies, some adolescents expressed skepticism about veracity of the social feedback task, which could have influenced neural response. Understanding the impact of beliefs about the deception element of the task would be possible if questions that allowed for a more explicit manipulation check had been included as part of the debriefing process.

Finally, while the present study contributes to the sparse literature that has examined cultural constructs in concert with ERP components to understand behavioral outcomes, there certainly are other variables that could have been measured to assist in unpacking results. Future research would benefit from precise and multifaceted measurement of socially transmitted cultural processes that are associated with critical changes across multiple domains of development (Fiske, 2002; Rogoff, 2003).

Conclusions and Future Directions

Among certain scholars there is understandable skepticism about the integration of culture and neurobiological processes. Some have argued that doing so leads to inappropriate reductionism (Wilson, 2000) or a lack of appreciation for the rich complexities of cultural processes. There has also been gross misapplication of cultural frameworks onto neurobiological outcomes to justify offensive pseudoscience related to topics such as racial hierarchies (Hartigan, 2015) and group differences in intelligence (Sternberg, Grigorenko, & Kidd, 2005). While certainly there are reasons to be hesitant about the integration of culture and neurobiology, if done in a thoughtful and meaningful way there is great potential to substantially push forward the knowledge base (Causadias, Telzer, & Lee, 2017). Continuing to silo the study of cultural processes from neuroscience only has the effect of perpetuating a biased, incomplete, and dichotomized (i.e., “nature versus nurture”) understanding of human behavior (Causadias, Telzer, & Gonzales, 2017). The present study represents a step toward bridging this gap and strengthening the field of cultural neuroscience. Concurrently, results should be interpreted tentatively and understood to be provisional. Culture is complex and occurs at multiple intersecting levels; in the present study, there was a focus on collectivism, but there are many other variables that constitute the larger-scale systems that shape the human psychological experience (Kendler, 2005).

Overall, there were several intriguing findings that emerged from the present study. Specifically, results supported the notion that collectivism increases the salience of social context for adolescents, which is reflected in enhanced neural response to errors when they occur as part of a team. Further, neural correlates of both error-monitoring and feedback response were related to a dimensional measure of social anxiety. These identified relationships appear to be contingent on certain factors, namely, how social context is represented (i.e., face image versus team) and the valence of social feedback. This project also draws attention to the importance of measuring both individual- and group-level constructs, as racial/ethnic group membership was found to moderate identified associations.

The ultimate application of this research is to inform the development and tailoring of intervention and prevention efforts. Translation of findings from research involving underrepresented groups is critical. In order to overcome the legacy of unethical biomedical research among underserved individuals and the corresponding mistrust that has been engendered as a result, it is imperative that the needs of underrepresented groups (e.g., improved interventions that address mental health disparities) be incorporated into research endeavors (Minkler & Wallerstein, 2008). More research is needed before translation can occur. A next step would be to longitudinally examine neural correlates of self-regulatory processes as mechanisms by which cultural values influence risk for psychopathology across development. As reviewed previously, adolescence is uniquely characterized by both increased vulnerability for and greater ability to intervene against maladaptive outcomes (Cohen Kadosh et al., 2013; Crone & Dahl, 2012; Haller, Cohen Kadosh, Scerif, & Lau, 2015; Nelson, Lau, & Jarcho, 2014). During this period, neurocognitive processes are thought to be more flexible which means that adolescents are highly sensitive to their environments but also that treatments may be particularly effective if delivered within critical windows. The present study represents a starting point in identifying neurobiological profiles that characterize culturally-influenced trajectories of psychopathology. This type of information can be leveraged, especially during periods of relative neural plasticity, to identify youth at risk for psychopathology and inform intervention approaches (Suleiman & Dahl, 2017). This framework is particularly amenable to the inclusion of culture, as psychopathology like social anxiety typically arises as youth experience normative changes in social environment, sensitivity to social information, and affective responding. Given that culture plays such a critical role in shaping how an adolescent navigates and experiences these processes, exploring the mechanisms by which cultural factors relate to the emergence of psychopathology can not only inform etiological understanding but also help to identify more precise treatment targets.

Appendix

Exploratory Correlations with Complementary Socioeconomic, Cultural, and Psychopathology Variables

Self-report measures. ***Youth perceived economic strain.*** One question taken from the demographics section of the National Comorbidity Survey Replication (Kessler & Merikangas, 2004) was used to assess youth perceptions of economic strain ("In general, would you say your family has more money than you need, just enough money for your needs, or not enough money to meet your needs?"). This item was rated on a scale from one ("More than needed") to three ("Not enough").

Religiosity. The Brief Multidimensional Measure of Religiousness/Spirituality (BMMRS) is an assessment tool for measuring religiousness and spirituality that was designed for health research (Fetzer Institute/National Institute on Aging Working Group, 1999). The measure has been validated in an adolescent sample (Harris, Sherritt, Holder, Kulig, Shrier, & Knight, 2008).

Acculturation. The Short Acculturation Scale for Hispanics-Youth (Barona & Miller, 1994) is a 12-item scale for Latinx youth that assesses level of acculturation to mainstream U.S. culture. Specifically, the SASH-Y assesses language use, media, and ethnic social relations. The scale correlates highly with length of residence in the U.S. and ethnic identification. In a Latinx youth sample (ages 10-16), internal consistency was found to be excellent ($\alpha = 0.92$) (Barona & Miller, 1994).

Acculturative stress. The Societal, Attitudinal, Familial, and Environmental Acculturative Stress Scale for Children (Hovey & King, 1996) is a 36-item measure designed to assess acculturative stress in school-aged children. The scale is designed to cover stressors as they arise in societal, attitudinal, familial, and environmental contexts. Internal consistency for this scale was found to be good in a Latinx youth sample ($\alpha = 0.82$) (Suarez-Morales, Dillon, & Szapocznik, 2007).

Depression. The Short Mood and Feelings Questionnaire (SMFQ; Angold et al., 1995), a 13-item questionnaire for which a score of 12 or greater indicates clinical depression. The full-length version of the scale demonstrates measurement equivalence across ethnic groups (Banh et al., 2012).

Correlations with ERN and FRN. ERN and FRN were exploratorily correlated with complementary socioeconomic, cultural, and psychopathology variables.

ΔERN_{Angry}. Acculturation and depression were negatively correlated with ΔERN_{Angry}, suggesting that as acculturation and depression increase there is greater differentiation between neural response to error and correct responses when primed by angry facial stimuli, acculturation: r= -.49, p=.02, depression: , r= -.32, p=.02.

ΔERN_{Team}. Religious coping was positively correlated with ΔERN_{Team}, suggesting that as religious coping increases there is less differentiation between error and correct responses when these responses occur in a social context, r=.22, p=.038.

FRN_{Accept}. Perceived economic strain and depression were negatively correlated with FRN_{Accept}, suggesting that neural response to acceptance feedback is enhanced as both economic strain and depression increase, perceived economic strain: r= -.22, p=.03, depression: r= -.26, p=.008.

FRN_{Reject}. Economic strain was negatively associated with FRN_{Reject}, suggesting that neural response to rejection feedback is enhanced as economic strain increases, r= -.27, p=.009.

Individualism and Collectivism Interact in Predicting ERN in the Team and Individual Conditions as Elicited by the Go/No-go Task

Individualism and racial/ethnic group were included as moderators in a regression model predicting ΔERN_{Team}, with age as a covariate. This model accounted for 24.85% of the variance in ΔERN_{Team}, $F(8,81)=3.34$, $p=.002$. Individualism and racial/ethnic group both interacted with collectivism in predicting ΔERN_{Team}, $F(1,81)=11.01$, $p=.001$, $F(2,81)=6.93$, $p=.002$, respectively. Probing of these interactions revealed conditional effects illustrated in Figure 12 such that Latinx and Asian adolescents who endorse low individualism differentiated more between error and correct responses in the team condition as collectivism increased, Latinx: $\beta=-.18$, $p=.001$, Asian: $\beta=-.21$, $p=.02$. NLW adolescents who endorsed moderate and high levels of individualism differentiated less between error and correct responses as collectivism increased, moderate individualism: $\beta=.10$, $p=.004$, high individualism: $\beta=.19$, $p=.0001$. This model suggested that Latinx and Asian adolescents appeared to demonstrate greater neural sensitivity in the social condition as a function of collectivism that was most apparent in the context of low individualism. Further, the association between collectivism and attenuated differentiation between error and correct responses was most pronounced for NLW adolescents in the context of moderate and high individualism.

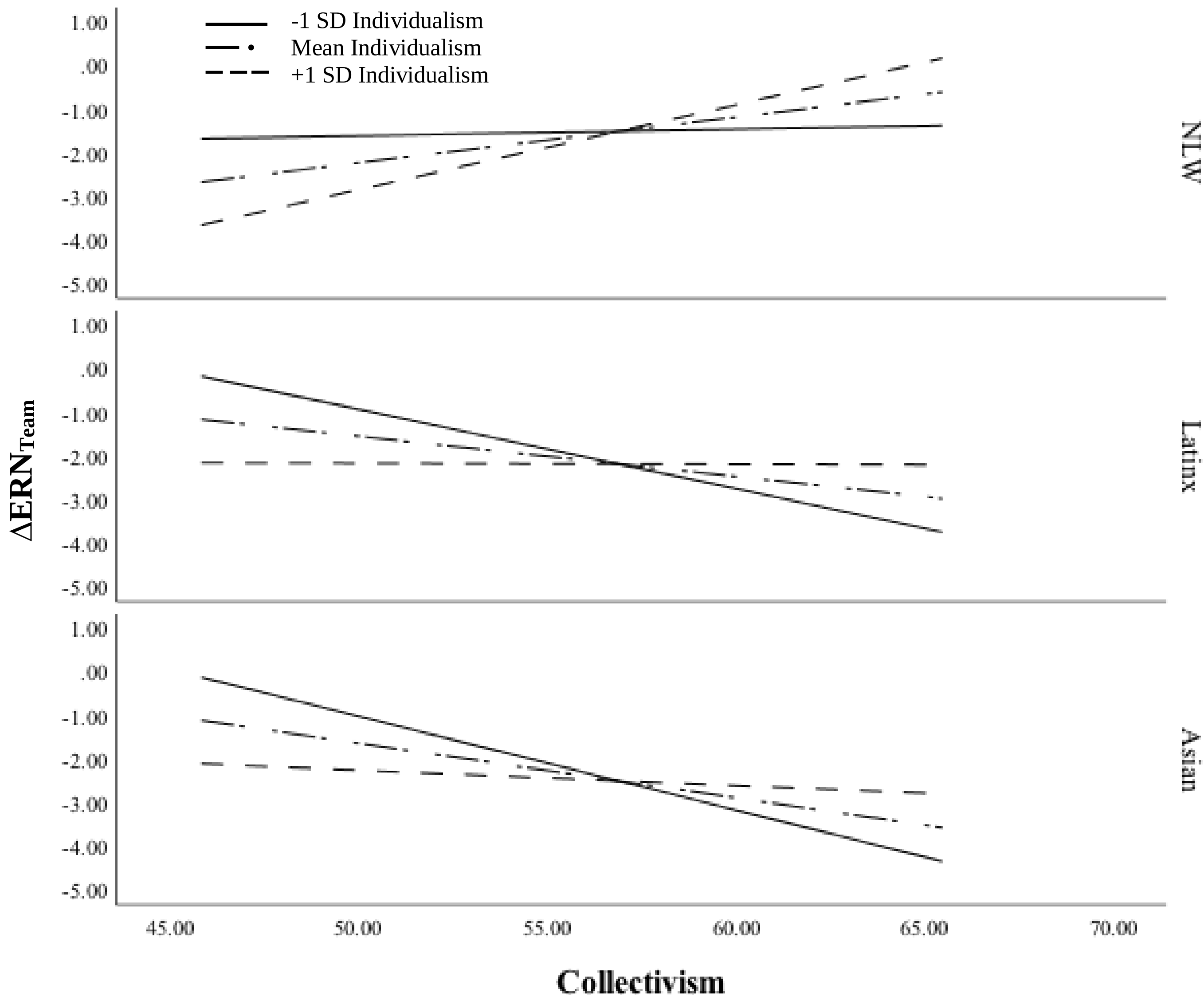

Figure 12. The association of collectivism and ΔERN_{Team} at -1 standard deviation, mean, and +1 standard deviation of individualism for NLW, Latinx, and Asian adolescents.

The next regression model tested collectivism and race/ethnicity as moderators of the association of individualism and $\Delta ERN_{Individual.}$ Race/ethnicity did not demonstrate a moderating effect, and as such, the variable and its interaction with individualism were removed from the model. The reduced overall model accounted for 17.99% of the variance in $\Delta ERN_{Individual}$, $F(4,85)=4.66$, $p=.002$. Collectivism interacted with individualism in predicting $\Delta ERN_{Individual}$, $F(1,85)=17.43$, $p=.0001$. Probing of this interaction revealed conditional effects illustrated in Figure 13. Individualism was negatively associated with $\Delta ERN_{Individual}$ for adolescents who demonstrated a low level of collectivism, $\beta=-.15$, $p=.0004$. A positive association was observed among adolescents who endorsed a high level of collectivism, $\beta=.08$, $p=.03$. This model demonstrated that greater individualism was associated with more differentiation between correct and error responses made in the individual condition and that the direction of this effect was reversed for adolescents endorsing a high degree of collectivism.

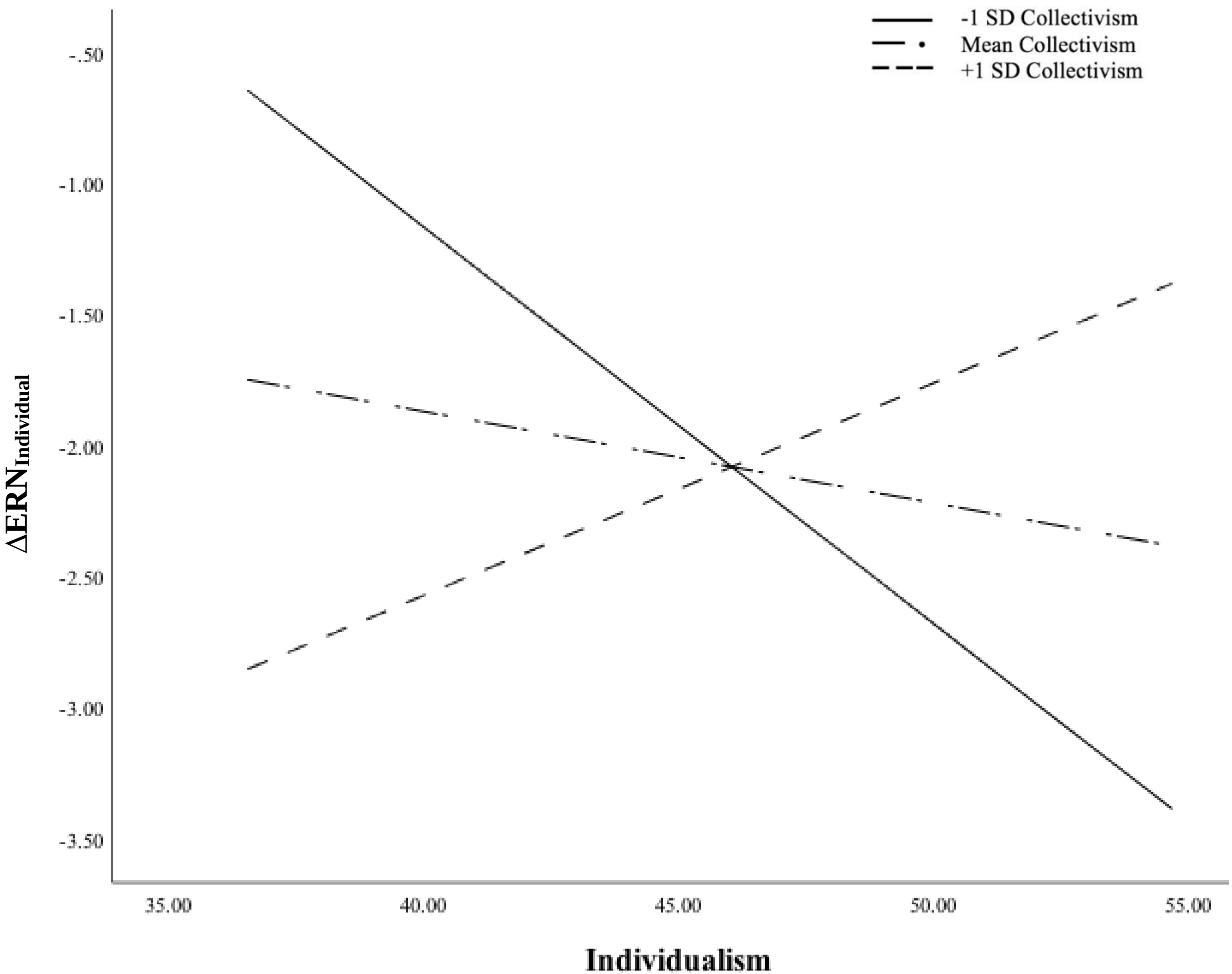

Figure 13. The association of individualism and ΔERN$_{\text{Individual}}$ at -1 standard deviation, mean, and +1 standard deviation of collectivism.

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